

PART II

MULTISOURCE CUMULATIVE HUMAN HEALTH ASSESSMENT: INHALATION

Chapter 3 Overview of a Human Health Multisource Cumulative Inhalation Assessment

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3.0 Background

The focus of this chapter is to:

- Provide an overview of the types of chemicals that may be present in a community's air and the sources of those chemicals;
- Provide an overview of multisource **inhalation** assessment [an assessment of additional non-inhalation pathways (e.g., ingestion and dermal exposures) – i.e., a **multimedia analysis** – is provided in Part III];
- Discuss some of the reasons a multisource analysis may be needed; and
- Identify and describe available approaches and tools for evaluating the cumulative inhalation impacts to human health, at the local level, from the multiple sources releasing air toxics in a study area.

A basic understanding of this information is necessary before beginning the planning and scoping process described in the next chapter. An illustration of how the release of air toxics can result in injury or disease is provided in Exhibit 3-1.

A Note on Terminology

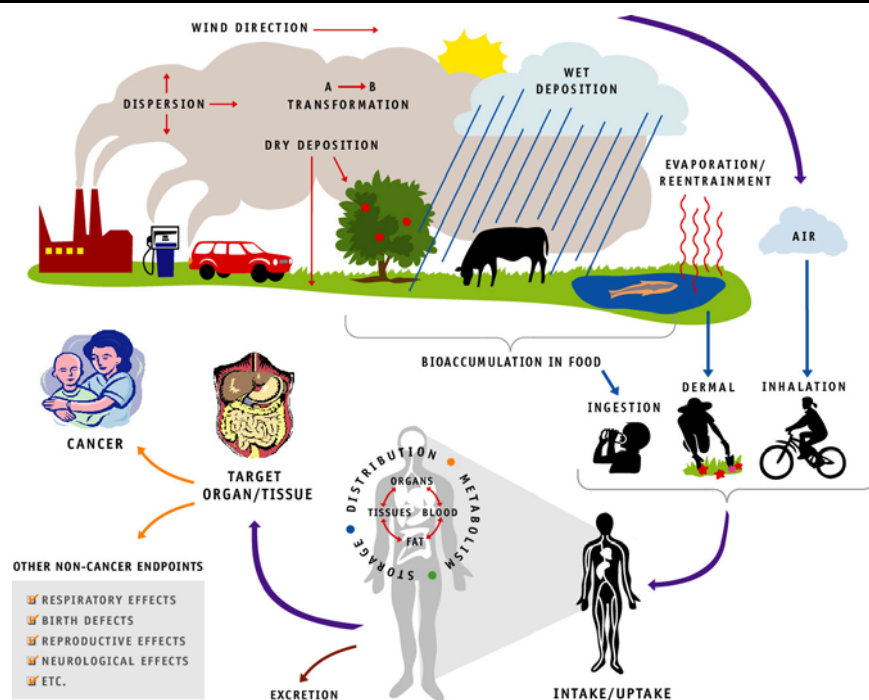
The focus of Part II is on assessing the combined inhalation impact of air toxics sources and the chemicals they emit on a the human population in a specific study area. There are several terms one could use to describe this combined impact analysis such as “multisource inhalation risk assessment,” “cumulative inhalation risk assessment,” or the more cumbersome “multisource cumulative inhalation risk assessment.” For the sake of brevity and clarity, Part II refers to this process simply as “**multisource cumulative assessment**.” This phrase encompasses the idea of multiple sources simultaneously impacting a study area and that the calculated risks are summed across all evaluated chemicals and sources. Including the specific route of exposure (inhalation) is superfluous given that Part II is relegated to inhalation-only exposures.

The terms “**air toxics**” and “**toxic air pollutants**” are often used interchangeably with “**hazardous air pollutants**” (which is a Clean Air Act phrase specific to the 187 pollutants that are the focus of section 112 of the Act – see <http://www.epa.gov/ttn/atw/188polls.html>).^{*} For the purposes of this reference library, however, the term “air toxics” is used in the more general sense to refer to any air pollutant (other than criteria pollutants) that has the potential to cause adverse impacts to human health or the environment.

“**Criteria air pollutants**” are six common air pollutants determined to be hazardous to human health and for which EPA has established National Ambient Air Quality Standards (NAAQS). The six criteria air pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. A detailed discussion of criteria pollutants is available at <http://www.epa.gov/air/urbanair/6poll.html>.

^{*}**A Hazardous Air Pollutant (HAP)** is defined under the Clean Air Act as a pollutant that causes or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Currently, the Clean Air Act regulates 187 chemicals and chemical categories as HAPs.

Exhibit 3-1. Generic Conceptual Model of How Air Toxics Releases May Result in Injury or Disease



Starting at the upper left hand side of this diagram, air toxics are released from one or more sources (e.g., factories, cars/trucks, small businesses, forest fires) to the air and begin to disperse by the wind away from the point of release. Once released, the chemical may remain airborne; convert into a different substance; and/or deposit out of the air onto soils, water, or plants. People may be exposed to air toxics by breathing contaminated air (inhalation, the focus of this part) or through ingestion of chemicals that can accumulate in soils, sediments, and foods (the latter process is called **bioaccumulation**; discussed in Part III). People also can be exposed to deposited chemicals via skin (dermal) contact; however, this tends to be a less important risk factor than ingestion or inhalation. Inhalation, ingestion, and dermal absorption are called the **routes of exposure**.

This description of what happens to a toxic air pollutant once it is released into the air is called **fate and transport** analysis. “Transport” evaluates how a toxic air pollutant physically moves (i.e., is transported) through the environment. “Fate” describes what ultimately happens to the chemical after it is released to the air (i.e., what is the “fate” of the chemical in the environment). The results of a fate and transport analysis is an estimate of the concentration of the toxic air pollutant in the air, soil, water, and/or food at the point where it is contacted by a person. The **exposure assessment** is the process of evaluating how human contact with the contaminated media occurs.

In the case of an air pathway analysis, the metric representing the inhalation exposure is called the **exposure concentration** (EC). For example, if benzene is released from indoor sources, mobile sources, gas stations, and a factory and all of this blows into a nearby neighborhood where people breathe it, the EC is the concentration of benzene in the air that they breathe.

Once an exposure occurs, toxic air pollutants can enter the body and exert an effect at the point of entry (the “portal of entry”) or move via the bloodstream to other target organs or tissues. The action of a pollutant on a target organ can result in no adverse effect or a variety of harmful effects, including cancer, respiratory effects, birth defects, and reproductive and neurological disorders. An overall risk assessment process evaluates what people are exposed to, how the exposure occurs, and, when combined with information about the toxic properties of the chemicals in question, estimates the likelihood that the exposure will result in injury or disease.

3.1 Introduction to Air Pollutants

Chapter 1 of this Volume introduced the terms “air toxics,” “hazardous air pollutants” (HAPs), and “criteria air pollutants.” This section will revisit each of these groups, as well as several other important chemical groupings, to provide more detailed information related to the chemicals on each of those lists. A thorough understanding of the different types of chemicals that may be of interest for a community-scale assessment, as well as the nuances of the various ways chemicals are written into those lists, will be important for the risk assessment team to comprehend before the assessment begins in earnest.

The term “air toxics” is a generic term that could conceivably encompass literally anything in the air that poses harm to people or the environment. For the purposes of this reference library, however, the term “air toxics” is used in the more general sense to refer to any air pollutant (other than criteria pollutants) that has the potential to cause adverse impacts to human health or the environment.

Risk Assessment for Air Toxics and Criteria Pollutants - What's the Difference?

This technical resource document is intended to provide a useful reference for assessing – at the community scale – cumulative risks associated with multiple air toxics emitted from multiple sources. Additional information regarding assessment of risks associated with the six commonly occurring **criteria pollutants**, including current standards and plain language fact sheets, is available at the following web sites: <http://www.epa.gov/ttn/naaqs/>, <http://www.epa.gov/ttn/fera/>, and http://www.epa.gov/ttn/fera/data/risk/naaqstbl_2003.pdf.

Several areas of potential crossover or overlap currently exist between the two pollutant groups. For example, ozone is formed by the interaction of volatile organic compounds (VOCs, many of which are air toxics), nitrogen oxides, and sunlight. As another example, particulate matter may be composed of a number of chemicals, such as nitrates and sulfates, organic and metallic compounds (many of which are air toxics), soil or dust particles, and allergens (such as fragments of pollen or mold spores). Lead is included in both the air toxics and criteria pollutant groups.

While the existence of separate programs for the criteria and hazardous air pollutants has generally led to the performance of risk assessments separately, even for the same locations, many of the same tools, methods, and programs may assist both the air toxics and criteria programs (e.g., emissions inventory development, monitoring programs for ozone precursors and particulate matter speciation, exposure model development, etc). However, differences in the nature of the information concerning the two sets of pollutants and in their associated policies and programs have contributed to differences in other assessment components, such as dose-response tools and risk metrics. Consequently, risk characterizations of situations involving some members of both sets of pollutants might be constructed as more of a “composite” than an integrated entity. Although a composite approach may be awkward, such composite risk characterizations would be more informative to the understanding of real-world exposures and risks than those that exclude one category or the other for reasons of analytical convenience. The Agency is, however, working toward a better understanding of cumulative health risks posed by all air pollutants collectively and the development of methods to facilitate more integrated assessments of air toxics and criteria air pollutants.

While the focus of most air toxics risk assessments will be on the 187 chemicals and chemical compounds listed as HAPs in the Clean Air Act (CAA) section 112(b), some assessment teams may wish to have a broader focus. The use of the term “air toxics” in this general sense is meant to provide for this flexibility. (In some cases, a community may want to go beyond the list of federal HAPs when assessing air toxics risks. It is for this reason that the partnership team must clearly understand why they are conducting an assessment and what chemicals and sources they want to include in that assessment.)

3.1.1 Introduction to Air Pollutant Lists

The various lists that are the focus of this technical resource library were all derived directly from the Clean Air Act, the Emergency Planning and Community Right to Know Act, or a specific EPA initiative (e.g., the PBT initiative list of chemicals – see Exhibit 3-3). It is important to keep in mind that there is not always consistency among these various lists in either the naming of chemicals or the meaning of the names. Specifically, the various lists of chemicals discussed below (e.g., HAPs, criteria air pollutants, TRI chemicals) do not always treat groups of chemicals (or chemical precursors/reaction products) in the same manner. Some examples of the ways in which these lists overlap or differ include the following.

- “Glycol ethers” are defined differently for the TRI and as HAPs (see box below).
- Ozone is formed by the interaction of NO_x , VOCs, and sunlight. Some of the HAPs are VOCs that may contribute to ozone formation.
- “Particulate matter” that is regulated as a criteria pollutant can be comprised of any number of individual chemicals and may contain various HAPs.

It is important to keep these overlaps and differences in mind since they can have important legal, policy, and other practical implications when studying air toxics impact or developing risk reduction alternatives for a particular location. The reader should also remember that the differences among chemical “lists” are based mostly on legal and regulatory considerations, not necessarily on toxicologic properties. It is also important to remember that some regulatory listings are comprised of multiple chemicals (e.g., polycyclic organic matter or POM), while toxicity data may exist only for the individual chemicals that make up the listing.

Glycol Ethers in the TRI and As HAPs

The Toxics Release Inventory (TRI) includes certain glycol ethers $\text{R}-(\text{OCH}_2\text{CH}_2)-\text{OR}'$ where:

$n = 1, 2, \text{ or } 3$

$\text{R} =$ alkyl C7 or less; phenyl or alkyl substituted phenyl

$\text{R}' = \text{H}$, or alkyl C7 or less

OR' consisting of carboxylic acid ester, sulfate, phosphate, nitrate, or sulfonate.

The list of HAPs includes mono- and di- ethers of ethylene glycol, diethylene glycol, and triethylene glycol $\text{R}-(\text{OCH}_2\text{CH}_2)_n-\text{OR}'$ where:

$n = 1, 2, \text{ or } 3$

$\text{R} =$ alkyl or aryl groups

$\text{R}' = \text{R}, \text{H}$, or groups which, when removed, yield glycol ethers with the structure: $\text{R}-(\text{OCH}_2\text{CH}_2)-\text{OH}$.

Polymers (surfactant alcohol ethoxylates and their derivatives) are excluded from the glycol category.

Lists of toxic chemicals commonly provide the chemical identity by both a name and a unique identifying number, called a **Chemical Abstracts Service (CAS) Registry Number**.^(a) However, most chemicals have multiple synonyms (sometime dozens). Fortunately, every unique chemical has only one CAS number and one can always refer to this unique number to identify the compound in question. For example, toluene and methylbenzene are synonyms for the same compound (which is normally referred to as toluene). However, there is only one CAS number for the compound: 108-88-3. No matter where one is in the world or what name is attached to a chemical, there is unanimity of identity through the CAS numbering system.

When there is any question about what a particular chemical name means, it is always advisable to try to pinpoint the identity through use of the CAS number. For example, a risk assessment team may ask for air sampling analysis for the HAP acetaldehyde (CAS number 75-07-0); however, when they receive the analytical lab report, acetaldehyde is not reported. A quick scan of the CAS numbers reported by the lab lists the CAS number 75-07-0 next to the name “ethanal.” Ethanal is a synonym for acetaldehyde and, hence, has the same CAS number. EPA’s *Handbook for Air Toxics Emission Inventory Development* includes a list of synonyms and CAS numbers for HAPs that is helpful in overcoming the nomenclature obstacle.⁽¹⁾ (Note, however, that there are nuances beyond this simplistic description. For example, some chemicals have one CAS number for their pure form and a different CAS number for a technical grade. A knowledgeable chemist can usually identify and clarify these issues.)

Some of the entries on chemical lists are for large groups of compounds and not just one single substance. For example, one of the HAPs is listed in the CAA as “polychlorinated biphenyls (aroclers)” and is most commonly referred to as PCBs. This listing is not for one single substance but, rather, for any one or a mixture of any of the 209 possible chemicals that are themselves PCBs. As another example, the pesticide “2,4-D” is written into the list of HAPs as “2,4-D (salts and esters).” This listing includes any possible salt of 2,4-D and any possible ester of 2,4-D. Likewise, the lead compound HAP listing includes any compound known to exist in or be emitted to the environment that contains a lead molecule as part of the compound’s molecular structure (a potentially huge number of possibilities). Another important group of chemicals is called “POM” for polycyclic organic matter. This includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100°C [e.g., polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene].

In reality, most risk assessments will deal with a relatively small number of chemicals because either the sources in a given place are releasing only a limited number of chemicals or the ability to model or monitor the numerous chemicals present is limited by the available inventories or monitoring/analytical methods, respectively.

In the initial stages of the assessment, risk assessors often sort the chemicals of interest into groups that generally have similar physical and/or chemical properties. This is a helpful thing to do as a way of making some educated guesses about how chemicals are likely to behave in the environment. The groupings also help an assessment team to plan for the types of sampling and

^a CAS (Chemical Abstracts Service) is a division of the American Chemical Society. A CAS Registry Number (CAS number or CASRN) is assigned in sequential order to unique, new substances identified by CAS scientists for inclusion in the CAS Registry database. Each CAS Registry Number is a unique numeric identifier; designates only one substance; and has no chemical significance. A CAS Registry Number is a numeric identifier that can contain up to nine digits, sometimes divided by hyphens into three parts. See <http://www.cas.org/faq.html> for more information.

analysis methods that will be needed, because the sampling and analytical methods tend to be broken out along these same lines. In general, all air toxics can be broadly categorized into three main groups, organic chemicals, inorganic chemicals, and organometallic compounds.

Organic Chemicals

Organic chemical compounds are composed of carbon in combination with other elements such as hydrogen, oxygen, nitrogen, phosphorous, chlorine, and sulfur. Organic compounds can generally be split into two different groups, based on their propensity to evaporate. The following such groupings are commonly employed by analytical chemistry laboratories for purposes of sample analysis.

- **Volatile organic compounds (VOCs).** These are organic chemicals that have a high vapor pressure and tend to have low water solubility.^(b) Simply put, VOCs have a high propensity to evaporate and remain airborne. Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, pharmaceuticals, and refrigerants, as industrial solvents, such as trichloroethylene, or produced as by-products, such as chloroform produced by chlorination in water treatment. VOCs are often also components of petroleum fuels (e.g., benzene in gasoline), hydraulic fluids, paint thinners, dry cleaning agents, and many consumer products (e.g., glues and adhesives, floor polishes, hair care products, air fresheners).^(c)

A subgroup of VOCs is termed **carbonyl compounds** and includes chemicals such as formaldehyde and acetaldehyde. While such chemicals are themselves VOCs due to their high vapor pressure, they are often grouped as a separate class from the VOCs because of the special sampling and analytical methods necessary to measure them in air.

- **Semivolatile organic compounds (SVOCs).** SVOCs are organic chemicals that have a lower vapor pressure than VOCs and, thus, have a lower propensity to evaporate from the liquid or solid form. Once airborne, they also tend to more readily condense out of the gas phase. Examples of SVOCs include most organic pesticides (e.g., chlordane), and certain components of petroleum, such as polycyclic aromatic hydrocarbons. Note that the demarcation between SVOCs and VOCs is not exact. For example, the two separate air sampling and analytical methods for VOCs and SVOCs will both usually detect naphthalene when present, indicating that this chemical is on the lower end of the VOC scale of volatility and on the higher end of the SVOC scale of volatility. In general, as chemicals increase in molecular weight and/or polarity, they become more SVOC-like.

^b The regulatory definition of VOC does not identify vapor pressure as a consideration. See 40 CFR 51.100(s).

^c VOC refers to volatile organic compounds that contribute to ozone formation as defined by 40 CFR 50.100(s) as ozone precursors. VOC is a subset of VOCs. VOC emissions inventory information is sometimes used to derive estimates for specific chemicals; when this is done, the VOC number is said to have been speciated.

Inorganic Chemicals

This group includes all substances that do not contain carbon and includes a wide array of substances such as:

- Metals (e.g., mercury, lead, and cadmium) and their various salts (e.g., mercury chloride);
- Halogens (e.g., chlorine and bromine);
- Inorganic bases (e.g., ammonia); and
- Inorganic acids (e.g., hydrogen chloride, sulfuric acid).

Organometallic Compounds

This group is comprised of compounds that are both organic and metallic in nature. The alkyl lead compounds that were added to gasoline to enhance its properties can be used for illustration. “Alkyl” refers to the organic portion of a compound which is attached to the inorganic metal lead. The result is a so-called “organometallic” material, a hybrid of both metallic and organic. (Note that salts, such as sodium benzoate, are usually classified as an organic chemical, rather than an organometallic compound.)

An understanding of the general characteristics of organic chemicals, inorganic chemicals and organometallic compounds will aid in planning a risk assessment and developing an appropriate analysis strategy. For example, most VOCs tend to remain airborne and also do not tend to bioaccumulate to the same extent as some of the non-volatile chemicals. Thus, if an assessment were being planned to evaluate the impact of a source from which only VOCs were released, it becomes less likely that a multipathway risk analysis will be necessary (since VOCs do not tend to migrate into soil or water and do not tend to bioaccumulate as strongly in living tissue).

In addition, the sampling and analytical methods available to test for chemicals in environmental media are generally broken out along the same chemical groupings noted above. Thus, if one were interested in testing for airborne chlordane (an SVOC), a VOC monitoring method would not be used. Detailed information on available monitoring methods and the chemicals for which they have been validated is provided in ATRA Volume 1, Chapter 10.

In air toxics studies, both individual substances and mixtures of substances are of interest. Particulate matter (PM), for example, is almost never comprised of just one substance; instead, PM is usually made up of numerous individual substances (sometimes in the hundreds). Both the physical and chemical nature of a mixture will influence the fate and transport of the chemicals in the environment as well as the potential for the mixture to cause harm. For example, a toxic chemical adsorbed onto the surface of a relatively large particle (> 10 microns in diameter) will usually be trapped in the upper portion of the respiratory system and either coughed/sneezed out of the body or swallowed. The same chemical adsorbed onto a very small particle (< 2.5 microns in diameter) has a much higher likelihood of being inhaled into the deep lung.

3.1.1.1 Hazardous Air Pollutants (HAPs)

The HAPs are a group of 187 specific chemicals and chemical compounds and are identified in section 112(b) of the CAA. The Agency provides additional information on the HAPs online.⁽²⁾ HAPs are pollutants known to cause or suspected of causing cancer or other serious human health effects or ecosystem damage. They include individual organic and inorganic compounds and pollutant groups closely related by chemical structure (e.g., arsenic compounds, cyanide compounds, glycol ethers, polycyclic organic matter) or emission sources (e.g., coke oven emissions). EPA may add or remove pollutants from the HAP list as new information becomes available, and since the original CAA was published, two chemicals (caprolactam and methyl ethyl ketone) have been delisted. In addition, one chemical (ethylene glycol butyl ether) was removed from the glycol ethers chemical category. A full list of the HAPs is provided in ATRA Volume 1, Appendix A.

When people talk about “air toxics risk assessment,” they generally mean assessments of risks associated with one or more of the HAPs. This is largely because of the CAA listing of 187 HAPs and its requirement under section 112(f)(2) (Residual Risk) that EPA assess the risks associated with HAPs that remain after the application of the Maximum Achievable Control Technology (MACT) standards (section 112(d) of the Act).^(d) However, given that this is a relatively short list of chemicals, many communities may want to go beyond this list when assessing risk. It is for this reason that assessors and other stakeholders in the partnership must clearly identify why they are conducting an “air toxics risk assessment” and what they want to include in that assessment.

In its National Air Toxics Strategy, EPA identified a subset of 33 HAPs as those posing the greatest risk in urban areas (see text box on following page). These 33 HAPs were selected based on a number of factors, including toxicity-weighted emissions, monitoring data, past air quality modeling analysis, and a review of existing risk assessment literature.

The national-scale assessment for 1996 (see Section 4.2.1.1) focused on 32 of these 33 Urban HAPs (dioxin was omitted) and also includes diesel particulate matter, which is used as a surrogate measure of diesel exhaust. The 1999 assessment expanded the evaluation to include 177 HAP plus diesel particulate matter.^(e)

EPA maintains information about emissions of HAPs in its National Emissions Inventory (NEI). An overview of the NEI is provided in ATRA Volume 1, Section 4.4.1 and also discussed in Chapter 4.

^d See ATRA Volume 1, Chapter 2 and Section 3.2.1 below for a discussion of existing regulatory requirements for HAPs.

^e In its health assessment document for diesel engine (DE) exhaust (<http://cfpub.epa.gov/ncea/cfm/dieslexh.cfm>), EPA examined information regarding the possible health hazards associated with this pollutant, which is a mixture of gases and particles. The assessment concludes that chronic inhalation exposure is likely to pose a lung cancer hazard to humans, as well as damage the lung in other ways depending on exposure. Acute exposures can cause irritation and inflammatory symptoms of a transient nature. Evidence for exacerbation of existing allergies and asthma symptoms is emerging. The assessment’s health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in the health assessment document will need to be reevaluated. Diesel exhaust is addressed in several regulatory actions and diesel particulate matter plus diesel organic gases are listed by EPA as a mobile source air toxic (see Section 3.2.3).

The Urban Air Toxics

In 1999, EPA identified a group of 33 HAPs (the *Urban Air Toxics*) as those most important to health risks in urban areas.

acetaldehyde	coke oven emissions	manganese compounds
acrolein	dioxin	mercury compounds
acrylonitrile	1, 2-dibromoethane	methylene chloride ^(b)
arsenic compounds	propylene dichloride	nickel compounds
benzene	1, 3-dichloropropene	polychlorinated biphenyls (PCBs)
beryllium compounds	ethylene dichloride ^(a)	polycyclic organic mater (POM)
1,3-butadiene	ethylene oxide	quinoline
cadmium compounds	formaldehyde	1, 1, 2, 2-tetrachlorethane
carbon tetrachloride	hexachlorobenzene	tetrachloroethylene ^(c)
chloroform	hydrazine	trichloroethylene
chromium compounds	lead compounds	vinyl chloride

^(a) also represented as 1,2-dichloroethane

^(b) also represented as dichloromethane

^(c) also represented as perchloroethylene

3.1.1.2 Criteria Air Pollutants

The “criteria air pollutants” are six substances regulated pursuant to Title I of the CAA, for which “criteria documents” are developed by the Agency prior to national standard setting decisions. There are already national ambient air quality standards (NAAQS) in place for each of these pollutants as well as established regulatory programs and activities in place to meet those standards (see Exhibit 3-2). However, they are discussed here because there is some crossover between the realm of HAPs and criteria pollutants. The more important crossover issues are discussed below.

- **Particulate matter.** NAAQS have been established for particles with an aerodynamic diameter less than or equal to 10 microns (called PM₁₀) and particulate matter with an aerodynamic diameter less than or equal to 2.5 microns (called PM_{2.5}).^(f) PM can be made up of as little as one or a few or as many as hundreds of individual chemicals. In many cases (and depending on the source of the PM), any number of specifically listed HAPs may be a part of the PM mix. It is for this reason that risk assessors may opt to evaluate the composition of PM and to include any identified toxic air pollutants in risk calculations.

^f In December 2005, the EPA proposed revisions to the national air quality standards for fine particulate matter and also for some coarse particles. For additional information, see <http://www.epa.gov/air/particlepollution/standards.html>.

Exhibit 3-2. National Ambient Air Quality Standards (NAAQS)			
Pollutant	Standard Value*		Standard Type
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m³)	Primary
1-hour Average	35 ppm	(40 mg/m³)	Primary
Nitrogen Dioxide (NO₂)			
Annual Arithmetic Mean	0.053 ppm	(100 µg/m³)	Primary & Secondary
Ozone (O₃)			
1-hour Average	0.12 ppm	(235 µg/m³)	Primary & Secondary
8-hour Average	0.08 ppm	(157 µg/m³)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 µg/m³		Primary & Secondary
Particulate (PM₁₀) <i>Particles with diameters of 10 micrometers or less</i>			
Annual Arithmetic Mean	50 µg/m³		Primary & Secondary
24-hour Average	150 µg/m³		Primary & Secondary
Particulate (PM₂.₅) <i>Particles with diameters of 2.5 micrometers or less</i>			
Annual Arithmetic Mean	15 µg/m³		Primary & Secondary
24-hour Average	65 µg/m³		Primary & Secondary
Sulfur Dioxide (SO₂)			
Annual Arithmetic Mean	0.030 ppm	(80 µg/m³)	Primary
24-hour Average	0.140 ppm	(365 µg/m³)	Primary
3-hour Average	0.500 ppm	(1300 µg/m³)	Secondary
* Parenthetical value is an approximately equivalent concentration			

For example, it is possible to collect samples of PM₁₀ for purposes of determining the types and amounts of individual substances contained in the particles. The risks posed by those individual chemicals may then be estimated for the inhalation route of exposure. Because particles with diameters greater than 10 microns are not generally inhalable, analysts usually select a PM₁₀ monitor to capture samples for risk assessment purposes rather than a total suspended particulate (TSP) sampler, because TSP would capture larger particles that do not penetrate very far into the respiratory tract (thus leading to an overestimate in inhalation risk associated with the specific pollutants studied). Note that this would not be true for particle-bound chemicals that exert their toxic effects through interaction with the nasal passages (e.g., irritation, absorption).

- **Ozone and other criteria pollutants.** Certain other criteria pollutants are not specifically listed as HAPs, but HAPs may lead to their formation or they may lead to HAP formation. For example, ozone is produced by the interaction of certain VOCs, oxides of nitrogen (called NO_x), and sunlight. As noted previously, many of the HAPs are VOCs and may play a role in ozone formation. In contrast, sulfur dioxide is a criteria pollutant that can be transformed in the environment into sulfuric acid which, in turn, may become part of a listed HAP (e.g., cadmium sulfate). In general, the criteria pollutants ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide are not usually considered in air toxics risk assessments.

EPA maintains information about emissions of criteria pollutants and criteria pollutant precursors in its National Emissions Inventory (NEI). An overview of the NEI is provided in ATRA Volume 1, Section 4.4.1 and also discussed in Chapter 4 of this volume.

3.1.1.3 Toxics Release Inventory (TRI) Chemicals

Data on TRI chemicals are reported pursuant to section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) of 1986 and section 6607 of the Pollution Prevention Act of 1990 (PPA). EPCRA and the PPA are intended to inform communities and citizens about chemical hazards in their areas. EPA and states are required to collect data annually on releases (to each environmental medium) and waste management methods (e.g., recycling) of certain toxic chemicals from industrial facilities, and to make the data available to the public in the TRI.⁽³⁾ EPCRA section 313(d) permits EPA to list or delist chemicals based on certain criteria. In a 1994 rulemaking, EPA added 286 chemical categories to the TRI chemical list. The TRI chemicals are listed in 40 CFR Section 372.65, and information about the 666 currently-listed TRI chemicals is provided online.⁽⁴⁾

The current TRI chemical list contains 581 individually listed chemicals and 30 chemical categories (including three delimited categories containing 58 chemicals), for a total of 612 separate chemicals. If the members of the three delimited categories are counted as separate chemicals then the total number of chemicals and chemical categories is 666 (i.e., 581 + 27 + 58). The TRI list of toxic chemicals includes most of the HAPs. Similar to the HAPs, the TRI chemicals include VOCs, SVOCs, inorganic compounds, and organometallic compounds.

The utility of the TRI for air toxics risk assessment is two fold. First, it provides a broader perspective of industrial emissions than the HAP list because it includes information on air releases of many hundreds of additional chemicals. Second, accessing TRI information is extremely quick and easy. Using the TRI Explorer search engine (<http://www.epa.gov/tri/tridata/index.htm>), one may quickly identify the location of emissions sources and the identity and quantity of chemicals released to the air. The data is also updated annually (as opposed to the National Emissions Inventory (NEI), a nationwide inventory of emissions developed by EPA, which is only updated triennially). However, other characteristics of the TRI data may limit their use for risk assessments (see Section 4.2.1.2).

3.1.1.4 Toxic Chemicals That Persist and Which Also May Bioaccumulate

Some toxic compounds have the ability to persist in the environment for long periods of time and may also have the ability to build up in the food chain to levels that are harmful to human health and the environment. For example, releases of metals from a source may deposit out of the air onto the ground where they remain in surface soils for long periods of time. Children playing in the area may ingest this contaminated dirt through hand-to-mouth behaviors. The chemicals in the dirt may also be taken up into plants through the roots and accumulate in foraging animals which are then, in turn, consumed by people. A discussion on this topic is provided in Part III.

3.1.1.5 Other Chemicals

The chemicals included in the various lists of air toxics described above – HAPs, TRI chemicals, and toxic chemicals that persist and which also may bioaccumulate – do *not* represent all of the chemicals potentially emitted to air in a given place. For example, EPA is required to maintain an inventory, known as the “Toxic Substances Control Act (TSCA) Inventory,” of each chemical substance which may be legally manufactured, processed, or imported in the U.S. The TSCA inventory currently contains over 75,000 chemicals (see: “enforcement programs” at <http://www.epa.gov/compliance/civil/index.html>). As noted previously, this does not imply that risk assessments are always missing important information. To the contrary, the actual number of chemicals used in significant amounts and released to air are relatively small compared to the number of chemicals known. Nevertheless, it is important to keep in mind that the ability to evaluate air toxics releases is limited by current technology, the lack of toxicity information for all but a relatively small number of chemicals and, in some cases, costs (e.g., a single sample for certain analytes such as dioxin can cost upwards of \$1,000 per sample, potentially making extensive sampling cost prohibitive).

The HPV Challenge Program

EPA, in partnership with industry and environmental groups, recently created a voluntary chemical testing effort, the high production volume (HPV) Challenge Program. This program was developed to make publicly available a complete set of baseline health and environmental effects data on HPV chemicals (those manufactured in, or imported into, the United States in amounts equal to or exceeding 1 million pounds per year). Information on HPV chemicals is available at <http://www.epa.gov/chemrtk/rtkfacts.htm>.

3.2 Sources of Air Toxics

Many anthropogenic and natural activities are sources of air pollutants. Examples of human activities that result in the release of air toxics include:

- Fuel combustion activities in power plants, factories, automobiles, and homes;
- Biomass burning and other agricultural activities;
- Use of consumer products, such as pesticides and cleaning agents;
- Commercial activities, such as dry cleaning; and
- Industrial activities, such as petroleum refining, chemical manufacture, and metal plating.

Sources of air toxics can be categorized in various ways – whether they occur indoors or out, whether they are stationary or mobile, by the amount of chemicals they release, or by other

approaches. For the purposes of this discussion, air toxics have been placed into several major groupings that track EPA's programs and emissions inventories. [Note that some differences in terminology exist (see Exhibit 3-3).]

- Point sources;
- Nonpoint sources;
- On-road mobile sources;
- Nonroad mobile sources;
- Indoor sources;
- Natural sources; and
- Exempt sources.

The first four categories are groupings of emission sources of HAPs and criteria air pollutants in the aforementioned NEI. The NEI is discussed in more detail as a source of quantitative emissions release data in Section 4.2.1.2.

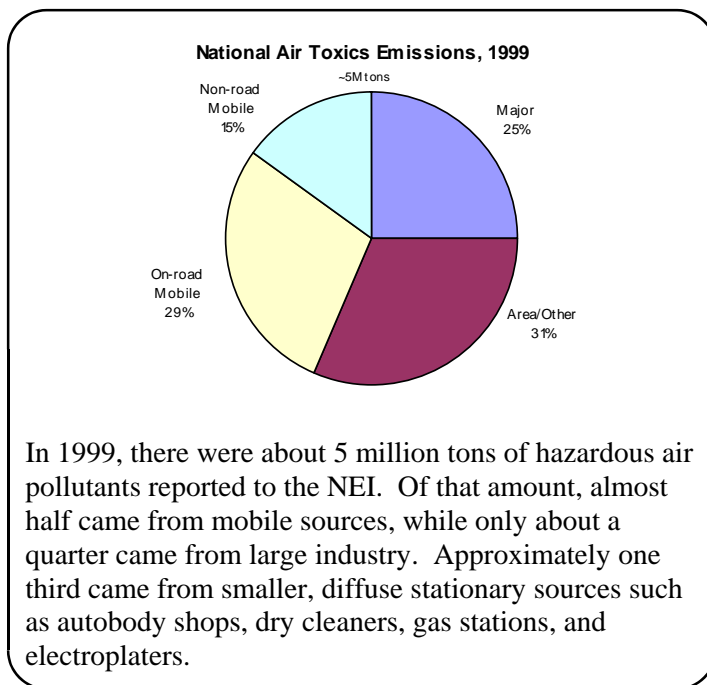


Exhibit 3-3. Terminology Related to Groupings of Source Types		
Source Type	How Defined in CAA	How Reported in NEI
Point source – Major	Point source – Major	Point source
Point source – Area	Point source – Area	Point source if location coordinates reported Area source if coordinates not reported
Nonpoint source	Nonpoint source	Area
Mobile source – On-road	Mobile source – On-road	Modeled
Mobile source – Nonroad	Mobile source – Nonroad	Modeled or estimated
Indoor	Not defined	Not reported
Natural	Not defined	Not reported
Exempt	Not defined	Not reported

3.2.1 Point Sources

Point sources of air toxics are stationary sources (i.e., sources that remain in one place) that can be located on a map. A large facility that houses an industrial process is an example of a point source – the facility and its emission release points (e.g., stacks, vents, fugitive emissions from valves) are stationary, and the emission rates of air toxics can be characterized, either through direct measurements, such as stack monitoring, or indirect methods, such as engineering estimates based on throughput, process information, and other data. The CAA divides point sources into two main categories primarily on the basis of annual emission rates:

- **Major sources** are defined in section 112(a)(1) as “any source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit, considering controls, in the aggregate, 10 tons per year (tpy) or more of any hazardous air pollutant or 25 tpy or more of any combination of hazardous air pollutants.”
- **Area sources** are defined in section 112(a)(2) as “any stationary source of hazardous air pollutants that is not a major source. For purposes of this section, the term ‘area source’ shall not include motor vehicles or nonroad vehicles subject to regulation under Title II.” Examples of area sources include dry cleaners, gas stations, chrome electroplaters, and print shops. Though emissions from individual area sources may be relatively insignificant in human health terms, collectively their emissions can be quite significant, particularly where large numbers of sources are located in heavily populated areas. Note that sources that are classified as “area sources” pursuant to the CAA may be reported in the NEI as “point sources” if they can be located on a map.

Many sources of HAPs are subject to **National Emission Standards for Hazardous Air Pollutants (NESHAPs)** pursuant to section 112 of the CAA. This section of the CAA directs EPA to issue regulations listing categories and subcategories (commonly referred to collectively as **source categories**) of major sources and area sources of HAPs and to develop standards for each listed category and subcategory.⁽⁵⁾ EPA periodically updates the list of source categories (see ATRA Volume 1, Appendix E).⁽⁶⁾

EPA regulates stationary sources in a two-phase process. First, EPA issues technology-based MACT standards that require sources to meet specific emissions limits. The emission limits are typically expressed as maximum emission rates, or minimum percent emission reductions, for specific pollutants from specific processes. In the second phase, EPA applies a risk-based approach to assess how well MACT emissions limits reduce health and environmental risks. Based on these **residual risk assessments**, EPA may implement additional standards to address any significant remaining, or residual, health or environmental risks (see ATRA Volume 1, Chapter 2 for a more detailed discussion of the MACT and residual risk programs).

Area sources may be subject to either MACT or **Generally Available Control Technology (GACT)** standards. GACT standards are generally less stringent than MACT standards. Area sources subject to MACT standards include Commercial Sterilizers using Ethylene Oxide, Chromium Electroplaters and Anodizers, Halogenated Solvents Users, and Asbestos Processors.

Physical Forms of Emissions

Air pollutants can be found in all three physical phases: solid, liquid, or gaseous. The distinct chemical and physical attributes of each phase contribute to the pollutant's transport and fate. Some of the common terms used to describe the form of a chemical in the atmosphere include:

<i>Gas</i>	A state of matter that is distinguished from solid and liquid states
<i>Mist</i>	Liquid particles measuring 40 to 500 micrometers that are formed by condensation of vapor
<i>Particulate Matter</i>	Fine liquid or solid particles

For example, as reported in the *Mercury Study Report to Congress*, gaseous elemental mercury vapor is not thought to be susceptible to any major process of direct deposition to the earth's surface due to its relatively high vapor pressure and low water solubility. Therefore, it is carried by the wind and subsequently dispersed throughout the atmosphere. However, divalent mercury, in either vapor or particulate phase, is thought to be subject to much faster atmospheric removal. For further details on fate and transport analysis, see ATRA Volume 1, Chapter 8.

3.2.2 Nonpoint Sources

The term nonpoint source refers to smaller and more diffuse sources within a relatively small geographic area. In the context of EPA's NEI, nonpoint sources of air toxics are stationary sources for which emissions estimates are provided as an aggregate amount of emissions for all similar sources within a specific local geographic area, such as counties or cities, rather than on a facility- or source-specific basis. Emission estimates for nonpoint sources are generated using "top-down" methods, when detailed information at the local level is lacking. Instead, the total emissions over a large geographic area (e.g., n tons in the northeastern states) are allocated to the local level (e.g., x percent is assigned to locality 1, y percent is assigned to locality 2, and so on). Note that for the purposes of this discussion, the nonpoint source category includes only stationary sources and does *not* include mobile sources.

Source-specific information may be available for *some* (but not all) of the specific facilities within a certain nonpoint source type. Area sources may be reported as either point or nonpoint sources in the NEI. If a state or local agency reports an area source emission as a point source, then the NEI retains the area source emission as a point source. The NEI does not aggregate point area sources as nonpoint sources, and **EPA has taken steps to avoid "double-counting" of emissions in the point and nonpoint source inventories.**

To compile nonpoint estimates for a category, the EPA first estimates county level emissions for nonpoint source categories. Then EPA replaces nonpoint EPA generated estimates with state, tribal, and local estimates. If a state, tribe, or local agency includes point source estimates for an EPA generated nonpoint source category, EPA removes the nonpoint estimate that it had generated and the point source inventory contains the S/L/T estimate. For example, in the Denver area, the State of Colorado inventories dry cleaners and service stations as point sources.

The NEI contains point sources estimates for these two categories in the six county area of Denver and the NEI does not contain nonpoint estimates for these two categories. Dry cleaners and service station emissions are contained in the NEI nonpoint inventory for the other fifty counties on Colorado.

A variety of sources are categorized as nonpoint sources in the NEI, including some small industrial/commercial processes (e.g., small dry cleaning facilities, hospital sterilization facilities, and dental offices). Additional nonpoint sources that contribute to air pollution are agricultural activities, residential trash and yard-waste burning, wood stoves and fireplaces, releases from spills and other accidents, and volatilization and resuspension of pollutants from contaminated sites. Examples of agricultural activities contributing to air pollution are biomass burning (e.g., for land clearing) and the application of fertilizers and pesticides. The open burning of forests are also categorized as nonpoint sources. Forest fires, including wildfires, are generally considered for the purposes of the NEI to be an anthropogenic source of air toxics because they are assumed to be directly or indirectly, for purposes of the NEI, caused by man.

Some nonpoint sources emit HAPs and are subject to NESHAPs pursuant to section 112 of the CAA (see ATRA, Volume 1, Section 4.3.1 for more information on NESHAPs). These nonpoint sources are area sources in that they emit less than 10 tpy of a single toxic air pollutant or less than 25 tpy of a mixture of air toxics. For example, facilities that perform perchloroethylene dry cleaning belong to a source category that is subject to NESHAPs.

3.2.3 On-Road and Nonroad Mobile Sources

Mobile sources pollute the air with fuel combustion products and evaporated fuel. These sources contribute greatly to air pollution nationwide and are the primary cause of air pollution in many urban areas. Section 202(l) of the CAA gives EPA the authority to regulate air toxics from motor vehicles. Based on 1996 National Toxics Inventory data (the NTI is the former name of the air toxics portion of the current NEI), mobile sources contributed 2.3 million tpy or about half of all air toxics emissions in the U.S. Mobile sources emit hundreds of air pollutants – for example, exhaust and evaporative emissions from mobile sources contain more than 700 compounds. EPA's Final Rule, *Control of Emissions of Hazardous Air Pollutants from Mobile Sources*, commonly known as the "Mobile Source Air Toxics" (MSAT) rule,⁽⁷⁾ identified 21 compounds as HAPs emitted by mobile sources (see text box below). All of these compounds except diesel particulate matter and diesel exhaust organic gases (DPM + DEOG) are included on the CAA section 112 HAPs list. Although some mobile source air toxics are TRI chemicals, mobile sources are not generally subject to TRI reporting. Other mobile source regulations address emissions of criteria pollutants and their precursors, including carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter (PM), volatile organic compounds (VOCs), and sulfur dioxide (SO₂). These criteria air pollutant control programs for mobile sources have and will continue to result in substantial reduction of HAP releases.

Mobile Source Air Toxics Listed in 2001 Rule⁽³⁾

- acetaldehyde
- acrolein
- arsenic compounds^(a)
- benzene
- 1,3-butadiene
- chromium compounds^(a)
- diesel particulate matter and diesel exhaust organic gases (DPM + DEOG)
- dioxin/furans^(b)
- ethylbenzene
- formaldehyde
- n-hexane
- lead compounds^(a)
- manganese compounds^(a)
- mercury compounds^(a)
- methyl tertiary butyl ether (MTBE)
- naphthalene
- nickel compounds^(a)
- polycyclic organic matter (POM)^(c)
- styrene
- toluene
- xylene

^(a) Although the different metal compounds may differ in their toxicity, the on-road mobile source inventory contains emissions estimates for total metal compounds (i.e., the sum of all forms).

^(b) This entry refers to two large groups of chlorinated compounds. In assessing their cancer risks, their quantitative potencies are usually derived from that of the most toxic, 2,3,7,8-tetrachlorodibenzodioxin.

^(c) Polycyclic organic matter includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100 degrees Celsius. A group of seven polynuclear aromatic hydrocarbons, which have been identified by EPA as probable human carcinogens (benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, 7,12-dimethylbenz(a)anthracene, and indeno(1,2,3-cd)pyrene) are used here as surrogates for the larger group of POM compounds.

Mobile sources include a wide variety of vehicles, engines, and equipment that generate air pollution and that move, or can be moved, from place to place. In the NEI, EPA divides mobile sources into two broad categories. **On-road mobile sources** include motorized vehicles that are normally operated on public roadways for transportation of passengers or freight. This includes passenger cars, motorcycles, minivans, sport-utility vehicles, light-duty trucks, heavy-duty trucks, and buses. **Nonroad mobile sources**, (sometimes also called “off-road”) include aircraft, commercial marine vessels (CMVs), locomotives, and other nonroad engines and equipment. The other nonroad engines and equipment included in NEI comprise a diverse list of portable equipment, such as lawn and garden equipment; construction equipment; engines used in recreational activities; and portable industrial, commercial, and agricultural engines.

Rulemakings and Voluntary Efforts to Reduce MSATs and Other Air Pollutants

- Tier 2 gasoline/sulfur rulemaking (<http://www.epa.gov/otaq/tr2home.htm>)
- Reducing nonroad diesel emissions (<http://www.epa.gov/nonroad/>)
- Voluntary diesel retrofit program (<http://www.epa.gov/otaq/retrofit>)
- Best Workplaces for Commuters (<http://www.commuterchoice.gov>)
- Clean School Bus USA (<http://www.epa.gov/cleanschoolbus>)
- It All Adds Up to Cleaner Air (<http://www.italladdsup.gov>)

EPA’s National Air Pollutant Trends Report, 1900-1998⁽⁸⁾ indicates that about 60 percent of mobile source air toxics emissions in the U.S. are from on-road sources, and 40 percent of mobile source air toxics emissions are from nonroad sources. The emissions distribution between on- and off-road sources emitting criteria pollutants depends on the chemical. CO comprises the majority of criteria pollutants emitted, with over 100 million tons per year emitted in the U.S. Releases of CO are *primarily* the result of mobile sources – like HAPs, these emissions are split approximately 60/40 between on-road and off-road sources. (The use of CO

as a monitoring surrogate for mobile source emissions is discussed in ATRA Volume 1, Section 4.4.1.)

Within the two broader categories of mobile sources, EPA further distinguishes on-road and nonroad sources by size, weight, use, horsepower and/or fuel type. For example, categories of on-road vehicles include light-duty gasoline vehicles (i.e., passenger cars), light-duty gasoline trucks, heavy-duty gasoline vehicles, and diesel vehicles. Examples of nonroad sources include nonroad *gasoline* engines and vehicles, (e.g., recreational off-road vehicles, construction equipment, lawn and garden equipment, and recreational marine vessels that use gasoline), nonroad *diesel* engines and vehicles (including the vehicles and equipment listed above, *except* those that use diesel fuel), aircraft, non-recreational marine vessels, and locomotives. An additional category covers all nonroad sources that use liquified petroleum gas or compressed natural gas.

3.2.4 Sources Not Included in the NEI or TRI

In addition to the four primary categories used in compiling the NEI, five other sources of air toxics which are not captured by either the NEI or TRI are described below: Indoor sources, natural sources, secondary formation of air toxics, exempt sources, and international transport.

3.2.4.1 Indoor Sources

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes (Exhibit 3-4). Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home.

There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

Diesel Exhaust and Community Health

Diesel exhaust contains significant levels of small particles, known as fine particulate matter. Fine particles are so small that several thousand of them could fit on the period at the end of this sentence. Fine particles pose a significant health risk because they can pass through the nose and throat and lodge themselves in the lungs. These fine particles can cause lung damage and premature death. They can also aggravate conditions such as asthma and bronchitis. In addition, in its health assessment for diesel engine exhaust, EPA concluded that chronic inhalation exposure is likely to pose a lung cancer hazard to humans. The assessment's health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in the health assessment document will need to be reevaluated (see <http://cfpub.epa.gov/ncea/cfm/dieslexh.cfm> for more information). Given the prevalence of diesel engines in communities, diesel exhaust will usually be an important factor in most community-scale multisource assessments and risk mitigation activities.

Who Is at Risk?

People with existing heart or lung disease, asthma or other respiratory problems are most sensitive to the health effects of fine particles. The elderly and children are also at risk.

Other Health and Environmental Effects

Diesel exhaust also contains pollutants that contribute to ozone formation (or smog), acid rain, and global climate change. Fine particles from diesel engines contribute to haze which restricts our ability to see long distances.

What's Being Done About It?

EPA is working aggressively to reduce pollution from new heavy-duty diesel trucks and buses, by requiring them to meet tougher and tougher emission standards in the future. In the meantime, there are a wide array of activities any community can adopt to help reduce exposure to diesel exhaust, including:

- Adopting anti-idling policies;
- Educating drivers and recognizing drivers that reduce idling time;
- Keeping diesel vehicles well maintained;
- Taking steps to retrofit existing vehicles with pollution controls;
- Replacing the oldest vehicles with new, clean vehicles; and
- Discouraging drivers from following directly behind other large vehicles, including school buses – especially if they see visible smoke being emitted.

For more information on diesel, its health effects and ways to reduce exposure, see <http://www.epa.gov/diesel/index.htm>.

Exhibit 3-4. Major Indoor Air Pollutants and their Sources	
Major Indoor Air Pollutants	Sources
Radon (Rn)	Earth and rock beneath home; well water; building materials
Environmental Tobacco Smoke (includes carbon monoxide, nitrogen dioxide, and respirable particles)	Cigarette, pipe, and cigar smoking
Biologicals (e.g., pollen, mold, animal dander, and fungi)	Wet or moist walls, ceilings, carpets, and furniture; poorly maintained humidifiers, dehumidifiers, and air conditioners; bedding; household pets
Carbon Monoxide	Unvented kerosene and gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, woodstoves, and fireplaces; gas stoves. Automobile exhaust from attached garages
Nitrogen Dioxide (NO ₂)	Kerosene heaters, unvented gas stoves and heaters. Environmental tobacco smoke
Volatile Organic Compounds (such as xylene)	Paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; dry-cleaned clothing
Inhalable Particles (such as particle-bound polycyclic aromatic hydrocarbons)	Fireplaces, wood stoves, and kerosene heaters. Environmental tobacco smoke
Formaldehyde	Pressed wood products (hardwood plywood wall paneling, particle board, fiberboard) and furniture made with these pressed wood products. Urea-formaldehyde foam insulation (UFFI). Combustion sources and environmental tobacco smoke. Durable press drapes, other textiles, and glues
Pesticides	Products used to kill household pests (insecticides, termiticides, and disinfectants). Also, products used on lawns and gardens that drift or are tracked inside the house
Asbestos	Deteriorating, damaged, or disturbed insulation, fireproofing, acoustical materials, and floor tiles
Lead	Lead-based paint, contaminated soil, dust, and drinking water
<p><i>Source:</i> U.S. Environmental Protection Agency and the United States Consumer Product Safety Commission. 1995. Office of Radiation and Indoor Air (6604J) EPA/402/K/93/007, April 1995. Available at: http://www.epa.gov/iaq/pubs/insidest.html.</p>	

In addition to the same indoor air problems as single-family homes, apartments can have indoor air problems similar to those in offices, which are caused by sources such as contaminated ventilation systems, improperly placed outdoor air intakes, or maintenance activities.

One particularly important indoor air toxics problem actually results from an outdoor natural source. In fact, radon gas, a HAP, is one of the leading causes of lung cancer in the U.S. The most common source of indoor radon is uranium in the soil or rock on which homes are built (thus, a natural source becomes an indoor air quality problem). As uranium naturally breaks down, it releases radon as a colorless, odorless, radioactive gas. Radon gas enters homes through dirt floors, cracks in concrete walls and floors, floor drains, and sumps. When radon becomes trapped in buildings and indoor concentrations build up, exposure to radon becomes a concern.

Sometimes radon enters the home through well water. In a small number of homes, the building materials can give off radon, too. However, building materials alone rarely cause radon levels of concern (see http://www.epa.gov/radon/risk_assessment.html for more information on radon risks). Exhibit 3-5 shows EPA's map of radon zones in the U.S.

3.2.4.2 Natural Sources

Natural processes are significant sources of some air pollutants, including VOCs, NO_x, O₃, PM and other pollutants (Exhibit 3-6). Examples of natural sources of air pollutants that are *not* covered by the four main categories described above include natural processes occurring in vegetation and soils (e.g., emissions from trees), in marine ecosystems, as a result of geological activity in the form of geysers or volcanoes, as a result of meteorological activity such as lightning, and from fauna, such as ruminants and termites. Sources associated with biological activity are called **biogenic sources**.

How Does Outdoor Air Enter a House?

Outdoor air enters and leaves a house by: infiltration, natural ventilation, and mechanical ventilation. In a process known as infiltration, outdoor air flows into the house through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by air temperature differences between indoors and outdoors and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchens, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the house. The rate at which outdoor air replaces indoor air is described as the air exchange rate. When there is little infiltration, natural ventilation, or mechanical ventilation, the air exchange rate is low, and pollutant levels can increase.

It should be noted that air toxics found in indoor air can originate from indoor sources, outdoor sources, or a combination of both indoor and outdoor sources. The concentrations that occur indoors and the actual exposures to people residing or working within a building will depend on a combination of factors, including infiltration and ventilation rates, characteristics of the indoor environment [such as indoor sources and personal activity patterns (e.g., time of day and length of time spent inside)], and other factors.

Natural pollutants contribute significantly to air pollution. For example, biogenic emission estimates for the United States were 28.2 million tons of VOC and 1.53 million tons of NO_x in 1997.⁽¹⁰⁾

Exhibit 3-5. EPA Map of Radon Zones

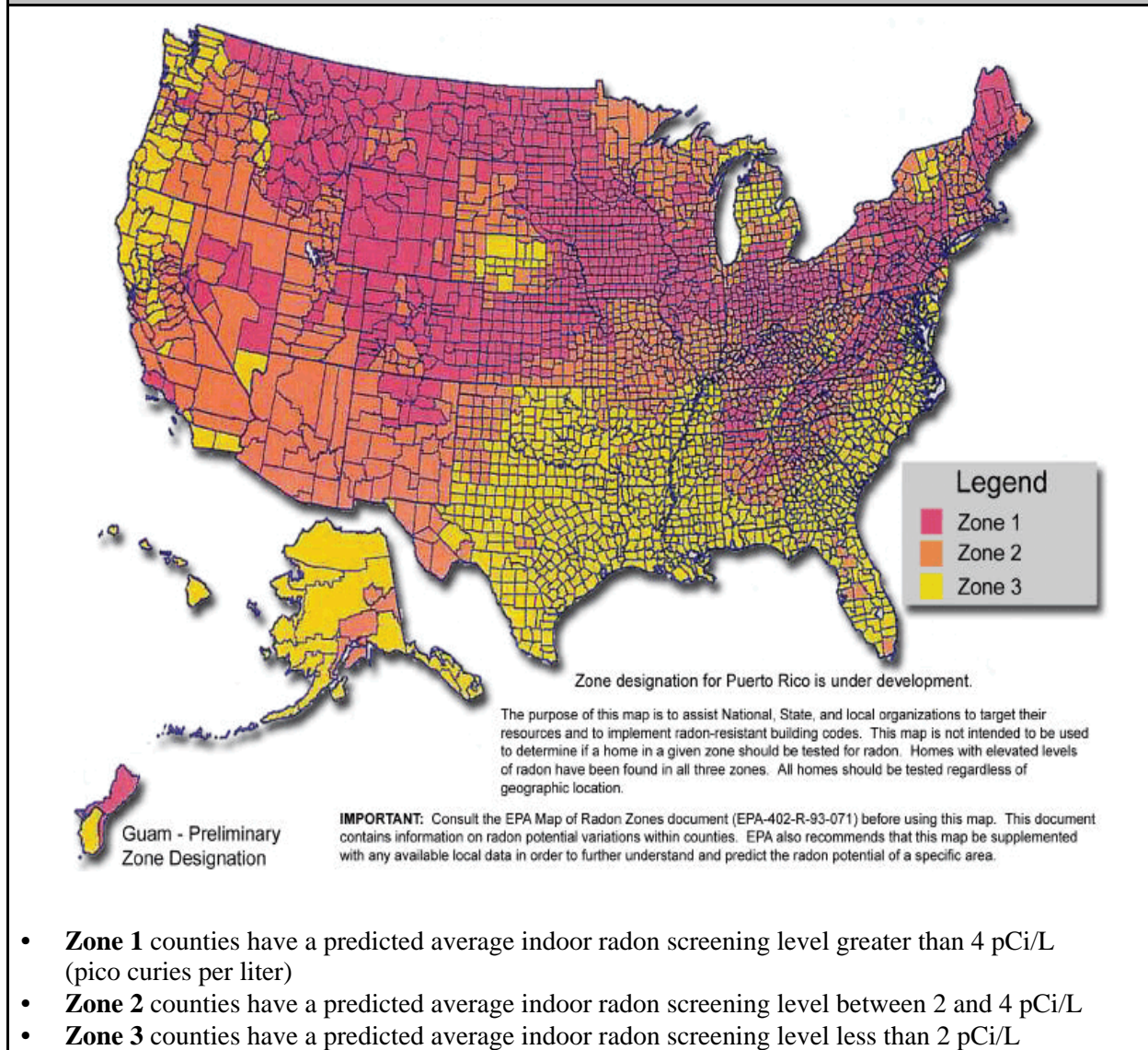


Exhibit 3-6. Categories of Natural Sources		
Category	Examples of Emissions	Sources
Geological	Sulphuric, hydrofluoric and hydrochloric acids	Volcanic gases
	Radon	Radioactive decay of rock
	Nitrogen oxides	Soils, lightning
Biogenic	Ammonia	Animal wastes
	Methane	Animal wastes, plant decay
	VOCs	Vegetation
Marine	Dimethyl sulfide, ammonia, chlorides, sulfates, alkyl halides, nitrous oxides	Sea spray released by breaking waves
Source: International Fertilizer Industry Association. 2001. Food and Agriculture Organization of the United Nations. <i>Global estimates of gaseous emissions of NH₃, NO and N₂O from agricultural land</i> . ISBN 92-5-104698-1. Available at: www.fao.org/DOCREP/004/Y2780E/y2780e01.htm .		

3.2.4.3 Formation of Secondary Pollutants

Some air pollutants, in addition to being directly emitted to the atmosphere by identifiable sources, are generated in the atmosphere by the chemical transformation of precursor compounds (a process called **secondary formation**). For example, under some meteorological conditions, up to 90 percent of ambient formaldehyde originates from secondary formation from a variety of precursor compounds in the presence of light (i.e., via a **photochemical reaction**). Some of the precursor compounds include isoprene (an organic compound released from trees), isobutene, and propene. The secondary formation of pollutants like formaldehyde and acetaldehyde is a complex process but can be estimated by some photochemical models (e.g., UAM-Tox, a special version of the Urban Airshed Model (UAM)). Other available models also address secondary formation but in a much more limited way (see ATRA volume 1, Chapter 9 for a more detailed discussion of air models).

The NEI and other emission inventories generally do not include estimates of pollutants formed through secondary formation – only the initially emitted species are included. Because the formation of secondary pollutants depends on the meteorological conditions and the presence or absence of other compounds and/or light, a model that incorporates chemical transformation algorithms is required to estimate how much secondary product is formed from precursor compounds once they enter the atmosphere. EPA has in some instances developed estimates of secondarily formed chemicals to better inform the assessment of exposure of people to toxic air pollutants. For example, for the 1996 NATA, National-scale Air Toxics Assessment, risk characterization exercise, EPA developed a special inventory of precursor compounds to supplement the NEI, which was used in conjunction with the Assessment System for Population Exposure Nationwide (ASPEN) model to calculate ambient concentrations (see <http://www.epa.gov/ttn/atw/natamain/>). Formation of secondary pollutants is discussed in greater detail in Chapter 5.

3.2.4.4 Other Sources Not Included in NEI or TRI

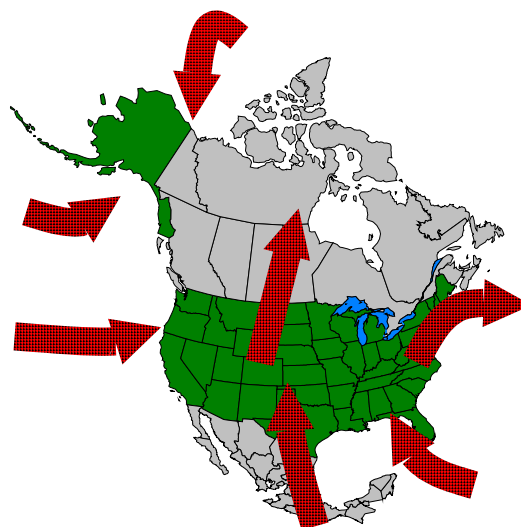
Many air toxics sources, usually relatively small ones, may not be covered or are exempt from various emissions control, reporting, and other requirements, and in some cases the number or stringency of requirements is tiered according to source size or other criteria. For example, air pollution regulations for municipal waste combustors (MWCs) promulgated pursuant to section 129 of the CAA include separate rules for large MWCs (i.e., with capacities greater than 250 tons per day) and small MWCs (i.e., with capacities between 35 and 250 tons per day). However, there are no rules for MWCs with capacities less than 35 tons per day.

International Transport of Air Pollutants

There is the potential for toxic chemicals that persist and which also may bioaccumulate to be transported from long distances to contaminate distant regions of the globe. An investigation by EPA Region 5 has shown the possibility of long-range transport of certain of these chemicals (identified in an international treaty as “persistent organic pollutants,” or POPs – see Exhibit 3-2) which were used in Central America prior to the 1980s to impact the Great Lakes. This is due to several phenomena. The semi-volatility of many POPs, allows them to be volatilized from warmer regions of the globe and redeposited in cooler regions in higher latitudes. Additionally, meteorological patterns during certain times of year can transport air masses and pollutants from the Central American region through the central U.S. into the northern states. Air masses from Central America have an unobstructed path to the Great Lakes (e.g. no physical barriers such as mountain ranges). Satellite photos show the transport of smoke from Central American fires in May of 1998 up through the Great Lakes Region.

This figure illustrates the mean wind flow at 1500 meters of altitude during the months of June, July and August from 1985 to 1996.

Although these patterns can be disrupted by climatological events such as El Niño, it is clear that POPs released in the southern areas of this hemisphere can impact areas of the U.S. Studies have shown that long range transport from many regions of the globe is a significant source of POP chemicals to the Great Lakes and that mitigation efforts are going to be needed both in the U.S. and globally to address potential sources. The study of Central American sources has shown that this region is a potential contributor to POPs contamination in the Great Lakes, due to the fact that these chemicals degrade very slowly, and there still exist areas of high contamination and stockpiles of these chemicals that are no longer in use in Central America.



For more information on International Issues & U.S. Air Quality, see EPA’s Air Trends website at <http://www.epa.gov/airtrends/international.html>.

Other miscellaneous sources of air pollution (e.g., agricultural and residential burning) are controlled primarily by other S/L/T requirements. However, EPA conducts research, provides information, and pursues other non-regulatory means of addressing some of these pollution sources. For example, EPA, in conjunction with the Consumer Product Safety Commission and the American Lung Association, has published a guide for reducing pollution from residential wood combustion, including design information for less-polluting stoves and fireplaces.⁽⁹⁾ Some local areas have ordinances that require new fireplace and wood stove installations to comply with the certification program, and others have ordinances that prohibit the use of a wood stove or fireplace on days that are conducive to the concentration of wood smoke emissions.

Ultimately, there is no single comprehensive source of information on all sources of air toxics in a given area. The NEI and TRI are good places to start an investigation of what is being released in a study area, but as noted above, in any given place, there are probably a number of air toxics sources that are not accounted for in these inventories. Nonregulated sources, natural sources, and material moving into a study area from distant sources all have an impact on overall air quality. Assessors need to clearly understand what these limitations are as they move into the planning and scoping stage of the risk assessment (see Chapter 4).

3.3 What Is Multisource Cumulative Assessment?

As described in this resource document, a human health multisource inhalation assessment is an evaluation of the ***estimated cumulative inhalation cancer risk and hazard to human health*** from multiple sources of multiple air toxics released to outdoor air to which the individuals in a study area may be exposed.^(g) The human health multisource inhalation assessment follows the same general principles as the human health risk assessment process described in ATRA Volume 1 of this series. A multisource assessment will normally consider a larger number and variety of emission sources, may rely on a more complex set of analysis tools, and may cover a large geographic area such as an entire community, a series of neighborhoods, or whole industrial corridors.

Risk assessment uses science and judgment to evaluate the following questions:

- Who is exposed to air toxics?
- What air toxics are they exposed to?
- How does the exposure occur?
- What concentrations are people exposed to?
- What are the toxic properties of the chemicals?
- How likely is it that exposed people will suffer harm because of the exposures?
- How sure are we that the answers to the above questions are correct?

Since study areas can be quite large and impacted by a complex mixture of sources of toxic air pollutant emissions, another distinguishing characteristic of a multisource assessment is the need to generate results in a manner that allows “backtracking” to the sources and chemicals most responsible for the estimated risks (a process called source allocation). Without a way to understand how different sources in the area contribute to the local mix of pollutants, the development of a meaningful risk mitigation strategy might prove difficult.

The primary exposure assessment methodology described in this resource document for the multisource cumulative assessment is a *modeling approach*. This type of approach relies on air

^g Refer to Section 4.3 for a discussion of exposure models and exposures to indoor air.

dispersion modeling to estimate concentrations of chemicals in air over space and time (a process called “fate and transport analysis”). The fate and transport results may be augmented by the application of an exposure model to develop refined estimates of exposure. The modeling approach is preferred for a community scale multisource assessment because it allows for: (1) a refined assessment of exposure gradients over a geographic study area; (2) a refined evaluation of exposures considering multiple time frames (acute vs. chronic exposures); (3) the evaluation of “what if” scenarios to determine the effects of changes in emissions; and (4) an identification of important sources (via source allocation).

A multisource cumulative assessment will commonly be supported by a limited amount of air quality monitoring in order to:

- Evaluate the air dispersion model results (e.g., by comparing to local NATTS or special monitoring study results);
- Identify gaps in the emissions inventory; and
- Help in the understanding of potential “hotspots.”

That having been said, communities performing such analyses often express a strong preference for monitoring over modeling as the key analytical tool for exposure assessment. Good planning and scoping (described in Chapter 4) that includes all the necessary stakeholders at the outset of an assessment (including community members) can usually resolve this issue by helping everyone fully understand the questions to be evaluated and the strengths and limitations of the available analytical approaches (a discussion of the strengths and limitations of monitoring and modeling for exposure assessment is provided in ATRA Volume 1, Chapter 10 and is highlighted in Exhibit 3-7).

For example, in a community with an expectation that an analysis will provide a full accounting of the incremental impact of the complex set of sources and emissions, it is incumbent on the risk assessment technical team to clarify that a limited monitoring study can generally provide only a screening-level understanding of risks, and will usually be limited in its ability to distinguish among contributing sources (information that is necessary when deciding how to fix the problem). This is because monitoring results may or may not be representative of a large spatial area and may be difficult to use for source apportionment, particularly when local sources are numerous and emit a common set of chemicals.^(h)

In short, air dispersion modeling will usually be the primary analytical tool for assessing air concentrations in a multisource cumulative assessment, while a limited amount of air monitoring will be used to provide important ancillary data. In some cases an exposure model will also be used to provide refined estimates of exposure. The correct balance of modeling and monitoring

^h The representativeness of an air toxics monitor’s results for a specific geographic area will depend on a variety of factors, including the chemicals in question, the area’s source characteristics, and the siting objectives of the monitor. For example, the concentration of Chemical X may be relatively homogeneous over a wide area, making the monitoring results from one central monitor representative of exposures over that area. A different chemical (Chemical Z) measured at the same central monitor may display a strong spatial gradient, making the Chemical Z monitoring results relevant for assessing exposures only to people located very close to the monitor.

Exhibit 3-7. Comparison of Modeling and Monitoring Approaches for Estimating Ambient Air Exposure Concentrations (ECs)

Modeling	Monitoring
Modeling is relatively fast and inexpensive compared to monitoring. Many screening-level models can be run in spreadsheet formats and require relatively simple input parameters. Many dispersion models, along with technical reference manuals and other support documents, are available for free download from EPA's Support Center for Regulatory Air Models (SCRAM) website (http://www.epa.gov/ttn/scram/). Resources normally need to be expended to enhance the local air toxics emission inventories to make air toxics modeling more precise.	With monitoring, it takes time to build data, and there are methodological limits and logistical issues. How expensive monitoring is depends on what you are trying to do and how much you are willing to pay. Monitoring does not always require equipment purchase, and some states, tribal, and local areas already have equipment. Some less expensive monitoring techniques are now available (e.g., passive samplers).
Modeling results can estimate concentrations over a large spatial area (e.g., a 50-km radius from a source) and can provide a "big picture" view of the assessment area. Modeling also allows for analysis of EC at multiple points throughout the assessment area. The downside of modeling, however, is that these are predicted concentrations.	Monitoring results provide actual measured concentrations. Multiple locations may be required to characterize concentrations over an area, although Geographic Information Systems (GIS) methods facilitate interpolation between locations. The downside is that the monitoring may not be representative of a large geographic area.
Screening-level models can provide a predicted estimate of whether significant concentrations are likely. A simple screening analysis may be sufficient to make a risk management decision that no action is required.	Monitoring can be used to identify and measure exposures for specific individuals at a specific location of concern (e.g., a school). This data can provide a quick screen to determine whether more extensive monitoring is needed.
Models can be used to identify areas where maximum concentrations are likely to occur, and thus where to focus efforts for additional tiers of the assessment. Uncertainties in model parameters and the discrete division of the wind field used in models (often with only eight wind directions) can result in incorrect identification of the locations of maximum concentration.	Monitoring can identify areas and actual levels of exposure occurring at the monitoring sites. Monitoring can also be used to indicate the point of maximal exposure if the monitoring is designed for that purpose. The selection of the monitoring locations is critical; if placed in the wrong locations, monitors can provide incorrect and misleading information about maximal exposures.
Models can be used to identify the subset of chemicals of potential concern (COPCs) and exposure pathways/routes that have the greatest contribution to risk. This can be helpful in focusing efforts for additional tiers of the assessment as well as determining appropriate risk management actions.	Monitoring can be used to confirm significant exposure pathways and routes. (Measured concentrations can be compared to risk-based screening levels). It also can be used to identify compounds that may not have been suspected and, hence, were not included in models (i.e., monitoring allows identification of gaps in the emissions inventory).
Models allow "what if" scenarios to be evaluated (e.g., what if a permitted emission were doubled?).	Monitoring can only evaluate current conditions.
More complex modeling may allow explicit predictions and estimates of variability in exposure.	A large number of samples generally is needed to characterize variability; this may be prohibitively expensive. Monitoring, however, provides a direct and reliable means to characterize variability.
Models often use simplifying assumptions and data inputs that may or may not be representative of the specific assessment area. This introduces uncertainty into model predictions.	Monitoring can be used to confirm actual exposure levels, to investigate assumptions or calibrate models to site-specific conditions, and to close gaps in data, reducing uncertainties.

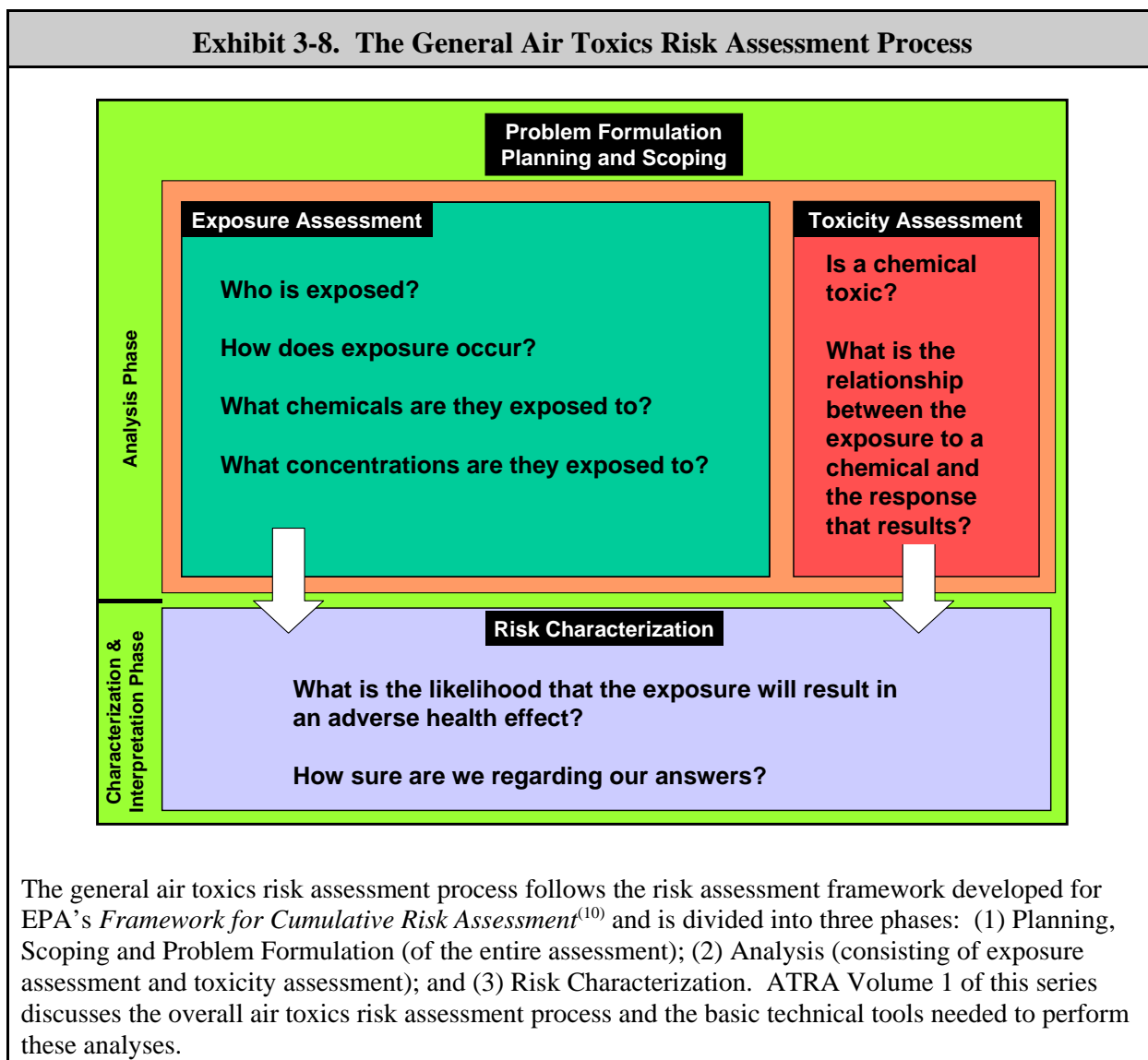
used in any given place will ultimately depend on the expectations and needs of the partnership team. A strong understanding of the strengths and weaknesses associated with the various modeling and monitoring approaches is crucial in order to correctly balance the modeling and

monitoring efforts. A more thorough discussion of modeling and monitoring can be found in ATRA Volume 1, Chapters 9 and 10, respectively.

Note that the success of a modeling effort will be strongly dependent on the quality of the emissions inventory available for the study area. It is for this reason that a significant emphasis will be needed to identify the quantity and quality of emissions inventory data needed for the effort, to review the existing emissions inventory data to see if it meets the identified data quality objectives, and to augment the existing inventory, if necessary. An overview of available inventories is provided in Chapter 4. Information on augmenting an existing inventory is provided in Chapter 5.

3.3.1 Overall Framework of a Multisource Cumulative Assessment

As introduced in ATRA Volume 1 of this series, the human health risk assessment process that forms the overall framework for any kind of air toxics risk assessment (single source or multisource) is divided into three main phases (see Exhibit 3-8; for an overview of this topic, see ATRA Volume 1, Section 3.3.2 and Volume 1, Exhibit 3-5).



- **Planning, scoping, and problem formulation** is performed to identify the assessment questions, state the quantity and quality of data needed to answer those questions, establish the scope of this analysis, provide an in-depth discussion of how the analysis will be done, outline timing and resource considerations, identify product and documentation needs, and identify who will participate in the overall process from start to finish, along with their roles. Planning, scoping, and problem formulation is regarded as an iterative process that allows for adjustment as new information is obtained. During this process, an identification and evaluation of available data and ancillary information about the study area will be performed to help identify key chemicals, sources, and potential exposures, to determine what kind of analyses can be performed, and to establish the data gaps which need to be filled. This will usually include obtaining and evaluating basic environmental data (e.g., existing air modeling and monitoring data), demographic data, citizen complaints, health studies and health outcome data (e.g., cancer statistics), and compliance/enforcement information (the types of data commonly evaluated at the outset of an assessment are described in Chapter 4).
- The **analysis phase** of the risk assessment is a process in which risk experts apply risk assessment approaches to evaluate the problem at hand (see ATRA Volume 1, Section 5.2.1 and Exhibit 5-1). Included in this phase are two important evaluations – exposure assessment and toxicity assessment. **Exposure assessment** is conducted to identify: (1) who is potentially exposed to air toxics; (2) what chemicals they may be exposed to; and (3) how they may be exposed to those chemicals, including the concentrations of chemicals in the air they breathe in. For a multisource cumulative assessment, these aspects of the exposure assessment are obtained through the analysis steps of emissions characterization, air dispersion modeling and application of an exposure model to the air modeling results. **Toxicity assessment** considers: (1) the types of adverse health effects associated with exposure to the chemicals in question; (2) the exposure circumstances associated with the effects (e.g., inhalation vs ingestion), and (3) the relationship between the amount of exposure and the resulting response (commonly referred to as the dose/response relationship).
- **Risk characterization** combines and summarizes the outputs of the exposure and toxicity assessments to characterize risk, both as quantitative (numerical) expressions and qualitative (descriptive) statements. Specifically, chemical-specific dose-response toxicity information is mathematically combined with modeled or monitored exposure estimates to give numbers that represent estimates of the potential for the exposure to cause an adverse health outcome. The risk characterization also provides a discussion of the variability in exposure and risk and uncertainties associated with the assessment. At this point, the assessors will also identify the key sources and chemicals that are responsible for most of the risk.

Like any air toxics risk assessment, multisource inhalation assessments follow the basic paradigm outlined in Exhibit 3-8. The defining feature of a multisource assessment, however, is the *scope of the exposure assessment*. Specifically, a multisource inhalation air toxics assessment aims to include (if possible) all the significant sources that contribute pollutant loadings to the air in the geographic area of interest. This will, at a minimum, commonly require consideration of a wide variety of emission source types such as major and area stationary sources and mobile sources (both on- and off-road). Depending on study objectives, the assessment may also include other sources such as forest fires, long range transport of pollutants into the study area, and indoor sources.

The overall database of emissions (the **emissions inventory**) may potentially include hundreds or even thousands of individual sources and the time and resource constraints on a project may limit the scope of a particular analysis to only a few key sources and chemicals of interest. For example, in a community impacted by large and small stationary sources as well as car, truck, train, and marine traffic, the cost to fully evaluate all these sources together using a robust modeling effort may be beyond the financial resources and time considerations of those conducting the assessment. As noted previously, the analysts may decide to first apply several simple screening-level techniques to help limit the number of sources and chemicals to be evaluated in the full modeling effort. The result is that the scope of the assessment, while not encompassing “all” sources, is focused on the most likely contributors to significant risk. This approach provides a more streamlined analysis which, if performed appropriately, should have little impact on the risk conclusions. A discussion of several common screening level approaches to narrow the focus of a multisource assessment is provided in the *How To Manual* (see reference 15), and Chapter 5 and Appendix B of this Volume.

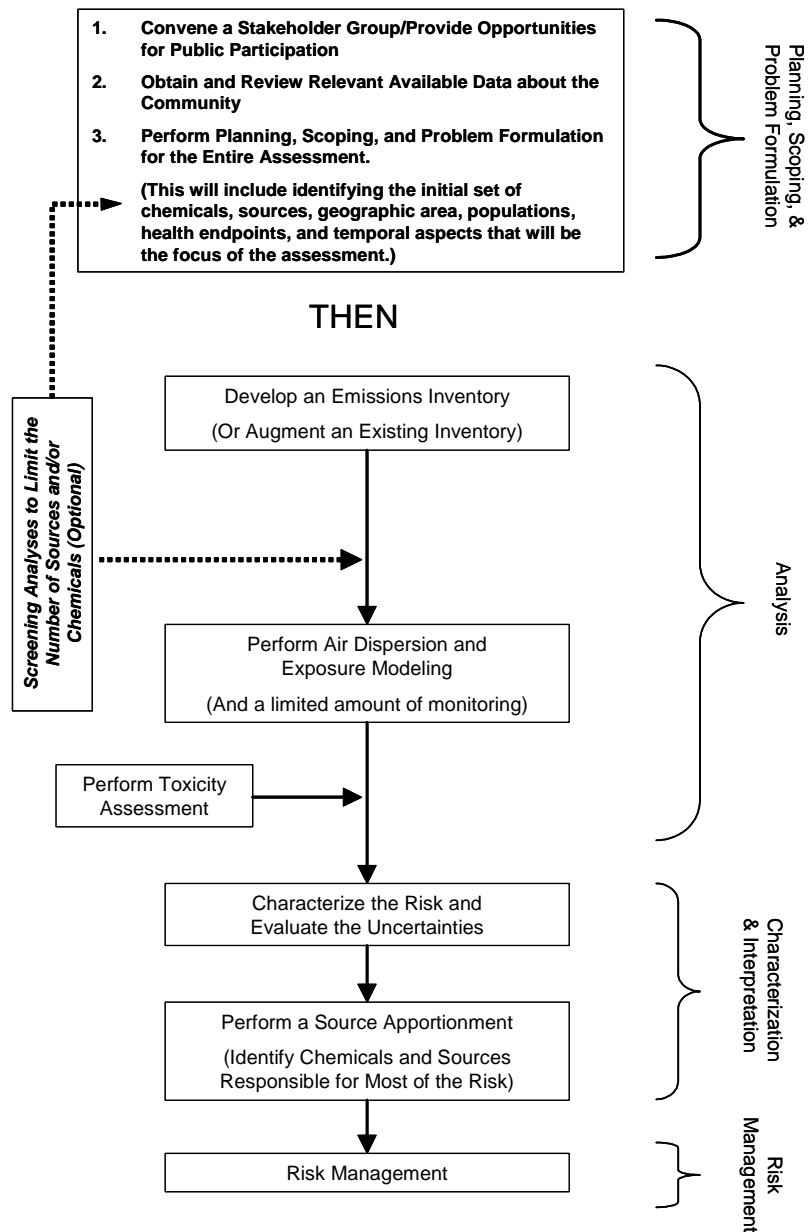
(Note that indoor sources can significantly contribute to a person’s overall exposure to air toxics, but the tools to include them in a multisource assessment are not fully developed. A discussion of including indoor sources in a multisource assessment is provided in Chapter 4. Readers interested in indoor air toxics are referred to <http://www.epa.gov/iaq/>.)

For a multisource cumulative assessment, it is helpful to take the general framework described in Exhibit 3-8 and redraw it to highlight the key activities that analysts performing a multisource assess will usually need to accomplish (Exhibit 3-9).

Each of the steps in the process illustrated in Exhibit 3-9 are discussed in detail in the following chapters. Specifically, Chapter 4 discusses planning, scoping, and problem formulation, Chapter 5 the analysis phase, Chapter 6 discusses risk characterization and interpretation, and Chapter 8 discusses risk management. An additional chapter highlighting important risk communication information is provided in Chapter 7.

While the general risk assessment framework outlined above identifies the main phases of risk assessment, important related activities include risk communication and risk management. Specifically, good risk communication skills will help in the planning of the assessment and in conveying the results to the community. In addition, decision makers will have to decide how to respond to the information that comes out of the multisource analysis. Chapter 7 and 8 discuss the risk communication and risk management aspects of a multisource analysis in detail.

Exhibit 3-9. The General Multisource Cumulative Assessment Process for a Community Assessment



3.4 Evaluating the Need or Usefulness of a Multisource Cumulative Assessment

The reasons why the partnership team may consider a multisource analysis to be necessary is usually based on existing information that points to a potential problem. Some of the most obvious information that people commonly look to in this regard includes:

- Existing emissions inventory data (National Emissions Inventory or NEI,⁽¹¹⁾ the Toxics Release Inventory or TRI,⁽¹²⁾ and SLT inventory and permit files);
- EPA's National Air Toxics Assessment (NATA) national-scale assessment risk characterization results for the study area;⁽¹³⁾
- Other screening-level air risk tool results (e.g., outputs from the TRI Risk Screening Environmental Indicators or RSEI tool);⁽¹⁴⁾
- Specific concerns voiced by citizens within the community;
- Existing community-specific monitoring and modeling data;
- Enforcement and compliance data on local business; and
- Existing epidemiological or other health outcome data.

A discussion of how to obtain and use these types of data to perform a preliminary evaluation of potential air toxics impacts at the local level is provided in Chapter 4.

When these data are considered together, they may paint a picture of a community with a potential air toxics problem that is the result of the combined impact of numerous sources emitting numerous chemicals. In such cases, it may make sense to pursue an assessment strategy that can both evaluate the combined risk and point to the sources most responsible for those risks.

In contrast, the partnership team may decide up-front that a simpler analysis will serve their purposes (e.g., a screening-level analysis using the approach described in EPA's *Community Air Screening How To Manual*, discussed in Section 3.5.1). The reasons for pursuing something other than a full-scale multisource analysis may include the following:

- Time considerations, financial and technical resources, or community support may make an expansive and as yet undefined multisource analysis untenable;
- The community may want to focus primarily on risks associated with only one type of source (e.g., risks posed by a specific local industry, risks posed by a concentration of mobile sources) and may have no interest in risks posed by combinations of source types;
- A desire by the community for a project that leads to "solutions" over the short term instead of a study that may be viewed as just "putting off the problem" (i.e., the community may have a strong "bias for action").

If the partnership team decides to perform an analysis of air toxics risks, there is no "one size fits all" approach for an assessment. Some partnership teams will opt to perform only a screening level approach, some will begin immediately with a comprehensive multisource assessment, and yet others will perform some level of screening to help them determine whether and how to proceed with a more comprehensive analysis. The local conditions and needs will usually drive the decisions on whether to simply take action, whether to take short-term action while proceeding with more formal analyses (either a screening level assessment or something more comprehensive), or whether to postpone action until analyses are complete.

The following section describes in more detail the logical progression analysts commonly take from an screening level approach to a more comprehensive multisource risk assessment. It should be emphasized that the choice of where to begin (and end) along this range of choices will depend on the needs and resources of the partnership team for whom the assessment is being performed.

3.4.1 Tiered Assessment Approaches

As discussed in ATRA Volume 1, Chapter 3, various EPA guidance documents and the Air Program's *Residual Risk Report to Congress* (available at http://www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf) recommend a ***tiered approach*** to risk assessments. A tiered approach is a process for a systematic, informed progression from a relatively simple evaluation of readily available data about a study area to a more complex, formal assessment of risk to area populations. In the lower tiers of analysis, a limited amount of data specific to the study area are usually evaluated using a relatively simple analytical framework. The people performing the evaluation will commonly try to counterbalance the use of limited data and analytical simplicity with a conservative set of assumptions that (hopefully) lead to conservative estimates of risk.

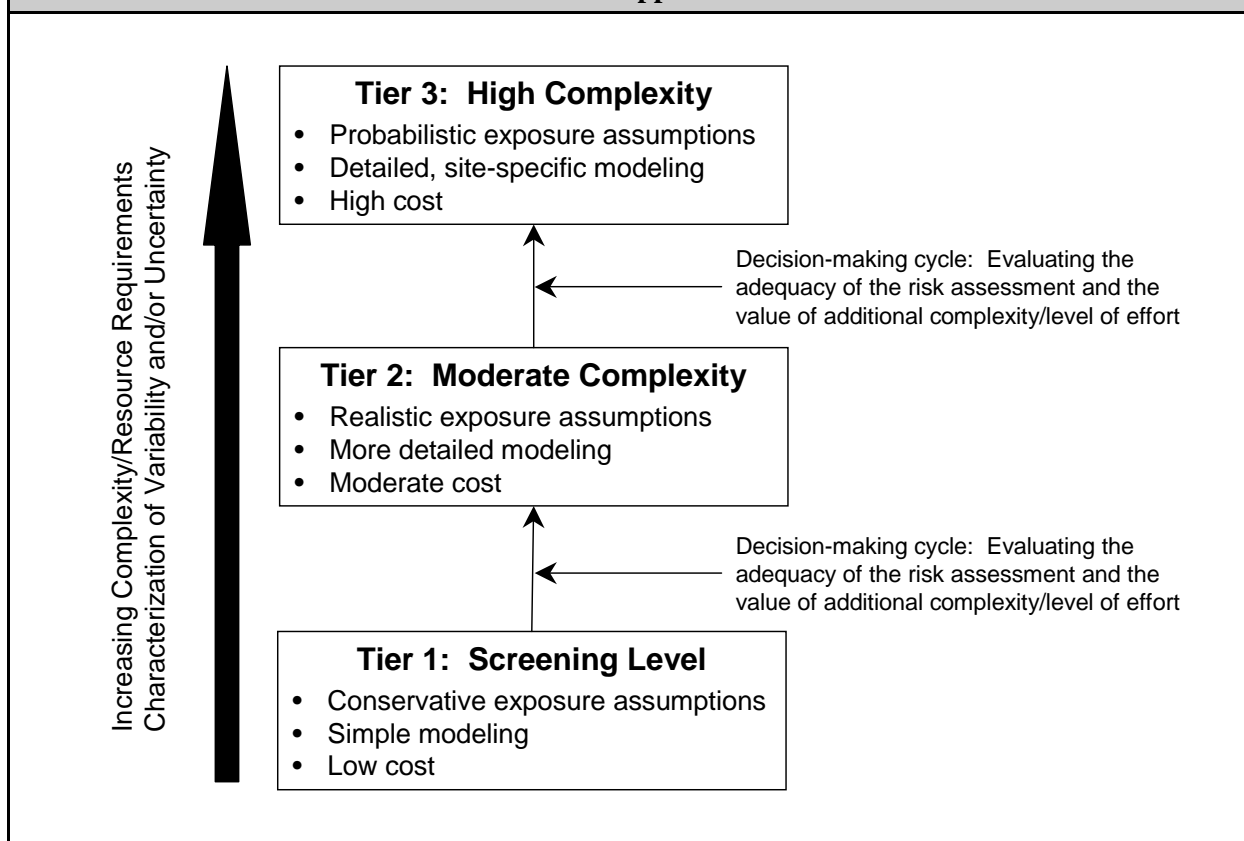
Such a process may be able to demonstrate, with relatively little effort, that the sources and chemicals being evaluated pose insignificant risk. On the other hand, if the approach indicates that the risk appears to be relatively high for one or more sources or chemicals, the analysts may decide to pursue a higher tier of analysis to clarify whether the risk is a realistic concern or an artifact of the lower tier's conservative assumptions. The higher level of analysis reflects increasing complexity and, in many cases, will require more data, time, and resources. The upside to the approach is (usually) greater confidence about the estimated impacts of the exposures being evaluated. Higher tiers may also be able to better characterize variability and/or uncertainty in the risk estimate, which may be important for making risk management decisions.

The deliberation cycle also provides an opportunity to evaluate the direction and goals of the assessment as new information becomes available. It may include evaluations of both scientific, policy, and other information.

In general, each of the Tiers represented in Exhibit 3-10 can be described as follows:

- **Tier 1** is represented as a relatively simple, screening-level analysis that relies on conservative exposure assumptions (e.g., receptors are located in the area with the highest estimated concentrations) and relatively simple modeling. The EPA's *Community Air Screening How To Manual* is an example of a Tier 1 type approach.
- **Tier 2** is represented as an intermediate-level analysis, generally using more realistic exposure assumptions and more detailed modeling (e.g., a model approach that evaluates the cumulative impact posed by multiple sources). The multisource approach outlined in Chapter 5 of this resource document (ATRA Volume 3) is an example of a Tier 2 type analysis.

Exhibit 3-10. The Generalized Tiered Approach to Air Toxics Risk Assessment



- **Tier 3** is represented as an advanced analysis using probabilistic techniques such as Monte Carlo analysis (see ATRA Volume 1, Chapter 31) or more detailed modeling (e.g., application of an exposure model).

Depending on the needs of the partnership team, they may begin with a relatively simple Tier 1 analysis and take actions based on the results. In contrast, they may decide to begin the process with a more formal multisource cumulative analysis. In some cases, they may develop Tier 1 results to help narrow the focus of the Tier 2 evaluation. If a fairly high level of understanding about emission impacts is required for the risk management decision, a Tier 3 analysis may be pursued for the most important chemicals and emission sources identified by the Tier 2 analysis.

Exhibit 3-10 illustrates a generalized representation of the tiered risk assessment approach. Central to the concept of the tiered approach is an iterative process of evaluation, deliberation, data collection, work planning, and communication aimed at deciding:

- Whether or not the assessment, in its current state, is sufficient to support the risk management decision(s); and
- If the assessment is determined to be insufficient, whether or not progression to a higher tier of complexity (or refinement of the current tier) would provide a sufficient benefit to warrant the additional effort.

Note that the tiered risk assessment approach provided in Exhibit 3-10 is not meant to imply that there is a clear distinction between Tiers 1, 2, and 3. For example, a series of refinements in a Tier 1 analysis might be indistinguishable from a Tier 2 analysis, or a Tier 2 analysis could incorporate probabilistic techniques. Instead, these three tiers are best thought of as points along a spectrum of increasing complexity and detail. The important focus is the specific ways in which a given assessment is refined in successive iterations, rather than whether or not it would be considered Tier 1, 2, or 3. (An additional discussion of screening approaches is provided in Appendix B.)

What Is “Screening” and When Would I Use It?

Screening is a process by which analysts apply some type of criteria to a group of issues to determine which of the issues is of sufficient concern to be considered for additional action. For example, in a community impacted by a large number and variety of air toxics emission sources and chemicals, analysts will commonly apply one or more techniques to try and “narrow the field” to those chemicals and sources that are probably the most important in terms of risk. This short list of sources and chemicals would then be the focus of more robust analysis or, potentially, immediate risk reduction efforts. The benefit of screening is that it can help reduce unnecessary work and help clarify what the important issues are for a community. The drawback is that, if not done properly, important information can be lost.

There are any number of “screening techniques” that could be used to limit the number of sources and chemicals in a community multisource analysis. The possibilities range from fairly arbitrary (and, thus, questionable) in nature to more scientifically objective. From a practical standpoint, the screening process usually takes shape in the form of an analysis that is performed in “tiers” (discussed above), with each tier having the flexibility to incorporate one or more screening techniques.

Analysts that are developing and/or using screening approaches should try to keep in mind that a good technique will usually need to meet three criteria:

- (1) The screening technique will be a relatively simple approach;
- (2) The inherent simplicity of the screening approach will be counterbalanced with reasonably conservative inputs and assumptions; and
- (3) The decision criteria used to evaluate the screening results will also be reasonably conservative.

If the analyst is not reasonably confident that the technique will not lose or “screen out” important information, the technique may not justify removing sources or chemicals from further consideration. In all cases, a thorough explanation of the rationale for dropping a chemical or source should be provided.

It should be emphasized that, depending on the specific goals, needs, data quality objectives, and resources of a given community-scale assessment, the number, type, and timing of screening level techniques may vary significantly. More information on screening level techniques relevant to multisource cumulative assessment is provided in Chapter 5, Appendix B, and the *Community How To Screening Manual* (see Section 3.5.1).

3.5 Methodologies for Multisource Cumulative Assessment

This section presents an overview of several example community-scale assessment approaches that illustrate the range and variety of available methodologies.

3.5.1 The OPPTS *How To Manual* Approach and Its Use in Baltimore, Maryland

EPA's Office of Pollution Prevention and Toxics (OPPT) has established a Community Assistance Technical Team to focus on providing tools and training to help communities to improve local air quality and move toward healthy and sustainable communities. As introduced in Chapter 2, one of their products, the *Community Air Screening How To Manual*,⁽¹⁵⁾ was developed as part of an effort to make air quality assessment tools more accessible to communities. Specifically, the Manual presents and explains a step-by-step **risk-based screening** process that a community may follow to:

- Form a partnership, including technical expertise;
- Identify and inventory all local sources of air pollutants;
- Perform a risk-based screening of these sources to identify those that may present a potential health risk to the community; and
- Set priorities and develop a plan for making improvements.

The methods described in the *How To Manual* were first developed by the Air Committee of the *Southern Baltimore & Northern Anne Arundel County Community Environmental Partnership (CEP)* in Baltimore, MD. In 1996, the residents, businesses, and organizations of five Baltimore neighborhoods joined with local, state, and federal governments in a CEP to begin a new effort to find ways to improve the local environment and economy. The CEP conducted a comprehensive screening-level assessment of the combined concentrations of air toxics from all the industrial and city facilities in and around the neighborhoods and developed a first-for-Maryland survey of cancer incidence at the neighborhood level. Based on this work, the CEP began work with local facilities on pollution prevention opportunities for chemicals and sources identified as community priorities. The risk screening methodology and lessons learned were documented in the *How To Manual* for community use. A detailed description of the work and

Resource Needs to Keep in Mind

Having example methodologies (such as the ones highlighted here) to consult when performing a multisource assessment is important; however, the partnership team will need to maintain a realistic perspective about the resources it will take to implement such a methodology. Typically, the time to identify a team of people to consistently work on and champion the project, plan and perform the analysis, interpret the results, implement selected risk reduction strategies, and measure results can take a number of years to complete.

Since many communities may not have access to the specialized technical skills that will be needed to perform various parts of the effort, they will need to recruit (and in some cases pay for) engineering, modeling, toxicological, and other experts. A long-term source of funding for all of the various elements of the project will be another important consideration.

These resource considerations should not discourage the team from pursuing the work. That having been said, a healthy appreciation of resource considerations and a willingness to communicate them openly will help to build and maintain trust with the larger community (especially if the team finds they have to reduce the scope of the effort based on limited resources).

results of the Baltimore Case Study is presented in the *Baltimore Community Environmental Partnership Air Committee Technical Report*.⁽¹⁶⁾

The community-scale analysis presented in the *How To Manual* is an approach that allows a community, working with the necessary technical support, to survey the types of sources that may be impacting their area and to use various screening level techniques to identify those sources and chemicals that may pose exposures of potential public health concern. The *How To Manual* complements the multisource inhalation air toxics modeling approach described in this resource document by providing communities with an understanding of how to organize and identify the needed skills to perform a screening level assessment. It also provides a basic description of the methodology and tools that can be used to provide a screening-level evaluation of the impact of sources on a specific geographic area. Application of this process can also point the community to the need for a full-scale multisource air toxics inhalation assessment. It can also help identify the critical sources and chemicals to focus on in that assessment.

3.5.2 Hotspots Analysis Reporting Program (HARP)

The Hotspots Analysis Reporting Program (HARP)⁽¹⁷⁾ is a software program designed specifically to assist with the California Air Resources Board's Air Toxics "Hotspots" Program. The HARP software package integrates the California emissions inventory, air modeling, risk analysis, and facility prioritization. HARP is a multisource, multipathway, publically available risk assessment software which utilizes conservative air and exposure modeling assumptions and inputs in accordance with the Hotspots Program. The HARP software can be used to assess the potential health impacts resulting from emissions from one or several sources that are close enough in proximity to each other that a single meteorological data set is appropriate. For the air modeling, it utilizes the EPA atmospheric modeling software ISCST3 and BPIP, and thus is capable of modeling point and area sources, but not mobile sources. It has been used to help California air pollution control and air quality districts, facility operators, and other stakeholders manage emissions inventory data and the health impacts associated with the data.

3.5.3 EPA Region 6 Regional Air Impact Modeling Initiative (RAIMI)

The Regional Air Impact Modeling Initiative (RAIMI) was established by EPA Region 6 as a means of assessing risk concerns on a community level as a result of aggregate exposure to multiple contaminants from multiple sources and pathways. RAIMI was designed to simultaneously calculate and track risks from hundreds or thousands of sources and contaminants based on various emissions scenarios (e.g., actual or estimated emissions data submitted by facilities to a state agency). As new or refined data become available, it can be directly incorporated into the assessment to obtain revised risk estimates on essentially a real time basis. Results from the RAIMI are generated in a fully transparent way such that estimated risk levels (using an assumption of continuous lifetime exposure to predicted air concentrations⁽ⁱ⁾) are completely traceable back to each source, each pathway and each contaminant. This allows for ranking of sources and contaminants based on the highest potential impact and helps risk managers to focus risk management opportunities on the most important

ⁱ The current set of RAIMI tools does not include the application of an exposure model; however, an exposure model could be applied to the results of the air dispersion modeling prior to taking the results forward into the next steps of the RAIMI process (i.e., risk calculation and source apportionment).

sources and chemicals first. A detailed description of RAIMI is available at:
http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm.

As a test of the RAIMI methods and approach, a Pilot Study was designed and implemented in Port Neches, TX. The initial phase of this study was to test the methods and approach for initial ranking of sources based on estimated risks resulting from direct inhalation, while a second phase (currently underway) is to study indirect exposures resulting from air-related sources. The initial pilot study successfully demonstrated the:

- Identification and ranking of emission sources and contaminants (modeled emission sources and contaminants were ranked based on relative potential impact);
- Identification of data gaps with the most significant effect on the ability to accurately characterize potential risks; and
- Options and flexibility to incorporate new or refined data as they become available (consistent with the design of RAIMI, findings are anticipated to change as source and contaminant emission data sets become more complete).

Automating the Multisource Risk Assessment Process *The RAIMI Toolbox*

Performing a full multisource cumulative assessment is conceptually straightforward but, depending on the number of sources and chemicals to be evaluated, can be computationally challenging.

The EPA Region 6 RAIMI program has developed a set of publicly available, user-friendly computer tools that seamlessly automate the multisource assessment process from mining and processing the emissions inventory data, to calculating and displaying risks, to source apportionment (see http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm). These tools are the most cohesive set of computer applications to date for full-scale multisource analysis and are highlighted throughout Part II of this resource document.

Note that, depending on the specific requirements of a given assessment, one or more of the RAIMI tools may not be the most appropriate. Thus, while the discussion in this Part highlights the RAIMI process, it also presents other options for each of the analytical steps within the multisource framework illustrated in Exhibit 3-9. Analysts should carefully select the set of tools that will allow them to meet the overall goals and objectives of their particular assessment. In addition to the tools highlighted here, commercial vendors offer products that can be used for various aspects of the analysis.

3.6 Choosing the Correct Tools and Approach for a Multisource Cumulative Assessment

While the conceptual framework for performing a multisource analysis is fairly straightforward (see Exhibit 3-9), performing an actual analysis can be complex. The specific tools and approach selected for each piece of the analysis will depend on both the established data quality objectives for the project and the time and resources available to do the work. For example, there are a variety of air dispersion models that can be used for a community-scale multisource analysis and analysts will need to choose the model that can evaluate their questions and meet their established data quality objectives (DQOs).

Data Quality Objectives (DQOs)

DQOs are qualitative and quantitative statements derived from the DQO process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support the decisions.

The following chapters provide a detailed discussion of each part of the conceptual framework illustrated in Exhibit 3-9 along with a selection of tools and approaches that are available for each the various parts of the process. Since the RAIMI approach for community-scale multisource cumulative assessment includes a comprehensive and cohesive set of computer tools that allows for a *seamless analysis and apportionment of multisource risks*, the RAIMI computer tools are highlighted within these chapters at relevant points.⁽ⁱ⁾ *Note that, depending on the specific requirements of a given assessment, one or more of the RAIMI tools may not be the most appropriate. Thus, while the discussion in this Part highlights the RAIMI process, it also presents other options for each of the analytical steps within the multisource framework illustrated in Exhibit 3-9. Analysts should carefully select the set of tools that will allow them to meet the overall goals and objectives of their particular assessment.*

ⁱ The RAIMI developers have gone to some lengths to make publicly available a seamless set of software, documentation, and real world examples that can readily be adapted to neighborhood or community-scale assessments. The remaining technical chapters of Part II relating to a full-scale multisource inhalation assessment closely follow the conceptual framework presented in the RAIMI methodology. Also note that RAIMI tools are currently focused only on the inhalation pathway. The RAIMI developers are working to expand their tools and concepts to multisource *multipathway* analysis as well. Analysts interested in this type of analysis are encouraged to check the RAIMI website for updates (http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm).

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